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LONDON

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Made and printed in Great Britain.

THE PLANKTONIC DIATOMS OF NORTHERN SEAS

BY

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WITH FOUR PLATES

LONDON

PRINTED FOR THE RAY SOCIETY

SOLD BY

DULAU & CO., LTD.

32, OLD BOND STREET, LONDON, W. 1

1930

PRINTED BY ADLARD AND SON, LIMITED
21, HART STREET, W.C. I.

R.377.30

PREFACE.

The author is indebted to the Council of the Royal Society for a grant towards the cost of publishing this book. Her best thanks are due to Miss G. E. Webb (now Mrs. Wheeler), who, while Temporary Naturalist at the Plymouth Marine Laboratory, prepared the original drawings for the greater part—and much the better part—of the text-figures. The figures from Mrs. Wheeler's drawings are indicated by the initials G. E. W., those drawn by the author by M. V. L. In the preparation of the book much help has been received from all members of the staff of the Laboratory, and the author wishes especially to record her indebtedness to the Director, Dr. E. J. Allen, for his invaluable advice and encouragement, to Dr. W. R. G. Atkins for reading most of the manuscript, to Mr. F. S. Russell for reading the proofs, and to Mr. D. P. Wilson for a collection of Diatoms from Rhos-on-Sea. She has also to thank all those who have kindly helped with advice, and by sending specimens and literature, especially Prof. H. H. Gran, Dr. C. A. Ostenfeld, Dr. E. Jörgensen, Prof. J. Pavillard, Prof. L. Mangin, Mr. Andrew Scott, Mr. H. B. Sutcliffe (for specimens from the Welsh coast), and Mr. E. Milton (for the drawing of auxospores on p. 10). Finally, she acknowledges her obligations to the many authors whose writings and figures have been freely quoted and used; above all to Prof. H. H. Gran, whose work on the Diatoms in 'Nordisches Plankton' is quoted on nearly every page.

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INTRODUCTION.

The present volume is intended to be a companion to 'The Dinoflagellates of Northern Seas'* and its form and plan are, as far as possible, similar. Gran's "Diatomeen" in 'Nordisches Plankton' (1905) is the standard work on marine planktonic diatoms, and this has been freely used. Whenever possible all synonymy is referred to it under each species. The term **Plankton** is given to the floating life which is dependent on currents, tides, winds and waves for its movement, as distinct from such life which can move about in the water actively. The **Phytoplankton** is the plant life of the plankton as distinct from the animal or **Zooplankton,** and the diatoms form by far the larger part of the phytoplankton.

The area covered is the same as in the 'Dinoflagellates'—not strictly defined, but mainly that of the International Investigations for the Exploration of the Sea, as it was up till 1927, excluding the Mediterranean. To the north the East Greenland Sea and Barents Sea are included, to the south the west coast of France, to the west Iceland and the North-Eastern Atlantic, and to the east Finland and the White Sea. Bigelow (1926) and Fish (1925) have shown that most of our northern planktonic diatoms are to be found on the American side of the Atlantic, and W. E. Allen (1921–28) has found many of the same species on the Californian coast.

Diatoms have long been favourite objects of study for the microscopist, but the marine planktonic forms

* 'The Dinoflagellates of Northern Seas,' by Marie V. Lebour. Published by the Marine Biological Association, Plymouth, 1925.

are not so generally known as they should be. The two reasons for this are probably firstly the supposed difficulty in collecting compared with **littoral** (coastal) species and freshwater forms, and secondly the quality of the cell-wall, which is usually much less strongly silicified in the floating forms, so that microscopic preparations are generally not so satisfactory. On the other hand their diversity of form makes them much more interesting, and it is hoped that this book will render the planktonic forms more familiar to all those interested in diatoms as a whole.

THE DIATOMALES OR BACILLARIALES (DIATOMS).

General Morphology.

The diatoms form a very large class of unicellular algæ occurring in damp soil, fresh and brackish water, and in the sea. Many live on the sea bottom or bottom of lake, river or estuary, and many live floating in the water—the planktonic forms. It is only those that live naturally floating in the sea which are included in the present work, except in a few cases where truly bottom forms occur quite commonly in the plankton. All are microscopic and many are exceedingly minute, but often are associated in such numbers that they are visible to the naked eye as brownish-green masses. In rare cases the single cells can be seen with the naked eye (*Rhizosolenia robusta*, *Coscinodiscus rex*). In size they range from 2 or 3μ (μ = a micron or one-thousandth of a millimetre) or less, to over one millimetre. Chains of cells may reach a length of 3 inches (Crawshay, 1914).

Each individual consists of one cell, often called a **frustule**, with an external skeleton composed of a matrix of pectin impregnated with silica (Mangin, 1908) of extremely variable form, inside which is the cytoplasm with the nucleus. The cytoplasm lies close up to the skeleton or **cell-wall** and usually contains large clear spaces, the **vacuoles,** which are full of sap. The nucleus is either at the side near the cell-wall or it occupies a central position in the cell, and strands of cytoplasm radiate from it to the cytoplasmic lining of the cell. Embedded in the cytoplasm are colour bodies, the **chromatophores,** of a greenish-brown, yellowish or greenish colour which are essential to the nutrition of the organism. It is only in exceptional cases that chromatophores are absent ; the diatom is

then **saprophytic**—that is to say, living on decayed organic matter.

The skeleton, which is secreted by the cytoplasm, is composed of two parts, the **valves,** each of which is bent at the edge at right angles to form a flange. A connecting band is attached to each flange. One valve, the older of the two, is always slightly larger than the other, and its connecting band fits over its companion like the lid of a box. The valves thus correspond to the top and bottom of the box, the bands corresponding to the sides. The bands of both valves together form the **girdle** (Fig. 1). The surface view of the valve is termed the **valve view ;** the side view showing the girdle is

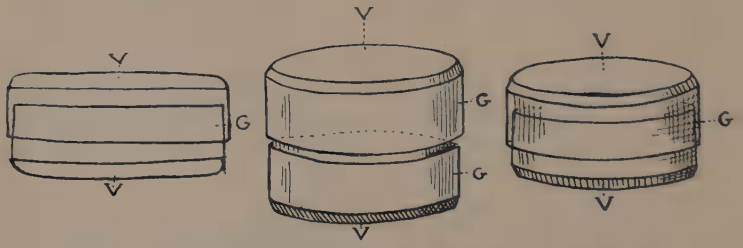


FIG. 1.—Diagram of *Coscinodiscus*, a typical box-like diatom. *v.* = valve, *g.* = girdle (G. E. W.).

termed the **girdle view.** The **cell axis** is the axis through the centre of the valves. The **length** of the cell is through the cell axis from valve to valve; the **breadth** is the diameter of the valve. Sometimes extra bands, the **intercalary bands,** may be present and the cell thus greatly elongated (Fig. 2*a*), and these may be thickened and may penetrate the cell-wall so as to divide it up into chambers, each division being termed a **septum,** the septa showing on the outside (Fig. 2*b*). The skeleton is sculptured in various ways, usually with small dots—the **puncta**—often arranged in lines, sometimes with large depressions—the **areoles**—which may be perforated for the exit of the cytoplasm, or there may be other pores in specialized parts of the valve (Müller, 1898). A large section, chiefly, however, consisting of bottom

forms, has the valve pierced by a slit, the **raphe** (Fig. 2 *c*, *d*), by means of which the cytoplasm is in contact with the water. It is in these forms that a certain movement is possible. This groove, which is usually in the middle of the valve surface, sometimes at the side or along the margin, has typically the appearance of a straight or curved line interrupted in the centre and lying in a special thickening of the cell-wall. The wall is also usually thickened in the centre, forming the **central nodule**, and at the ends there may also be thickenings, the **terminal nodules.** *Navicula* and its relatives have a typical raphe down the median line of each valve, with central and terminal nodules, *Surirella*

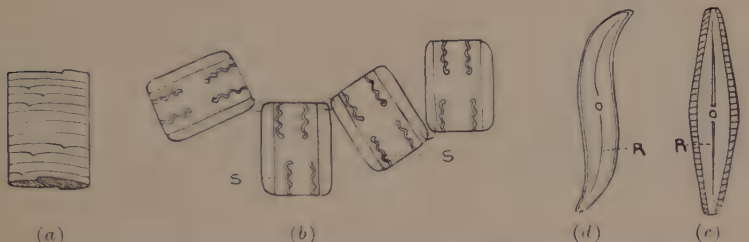


FIG. 2.—(*a*) Diagram of *Guinardia flaccida* showing intercalary bands; (*b*) of *Grammatophora serpentina* showing septa, *s.*; (*c*) of *Navicula* sp.; and (*d*) of *Gyrosigma* sp. showing raphe, *r.* (G. E. W.).

having wing-like expansions at the edges of the valves which contain the raphe. Some diatoms such as *Achnanthes* have a raphe on one valve only, the other having a narrow differentiated area but no cleft, known as the **pseudoraphe.** Others have only a pseudoraphe, as in *Fragilaria*. All these forms having their sculpture arranged in connexion with a longitudinal line belong to the **Pennatæ**; those having the sculpture arranged round a central or lateral point, or points, but never in connexion with a straight line, are known as the **Centricæ.** These latter are not capable of free movement, and to this group most of the planktonic diatoms belong.

The power of exuding cytoplasm is a property of nearly all diatoms, which at certain times may be enveloped in a kind of mucilage from this source, often used as a protection in uncongenial surroundings. The minute strands of cytoplasm often come from small raised points which are perforated. These, as in most *Coscinodiscus* species, *Thalassiosira* and many other related forms, are frequently arranged round the margin of the valves. The term **spinulae** (singular, **spinula**) used here was suggested by Dr. C. H. Ostenfeld to the writer for these raised points, which are often produced as small spines, the term **apicule,** frequently used in the same sense, being reserved for those larger marginal nodules found in certain species, usually occurring asymmetrically (the **Biapiculati** in the genus *Coscinodiscus*, for instance). The cytoplasmic rays of *Thalassiosira* and its allies coming from the spinulæ are characteristic, and the gelatinous masses in which the cells of *Thalassiosira subtilis* and certain species of *Chætoceros* are embedded show the culmination of such exudations. Mangin (1908) has shown how very commonly the cytoplasm makes its exit from the cell in various ways. Sometimes the surrounding mucilage is useful in maintaining as constituents of the plankton diatoms usually of bottom habit, as in *Actinocyclus Ehrenbergi* (see Ostenfeld, 1908*a*), and *Grammatophora marina* (see Lloyd, 1926). The chains formed by so many species, mostly of truly planktonic forms, are held together by cytoplasmic connexions coming from various parts of the cell.

Planktonic diatoms are extremely variable in shape (Fig. 3), and are adapted for flotation by being connected in chains, by the presence of long spines or by the extreme elongation or inflation of the cell itself. In those living singly, especially in the disc-shaped forms, the vacuoles containing oil may tend to keep them afloat. They may be pillbox-shaped, cylindrical, cushion-shaped, needle-like, or spindle-shaped and often twisted and curved. The cells may be connected into

chains by a cytoplasmic thread, or by several threads, or by spines, or they may be joined by pads of cytoplasm or by the valve surfaces. In rare cases the cells move upon one another with a gliding motion (Bacillaria).

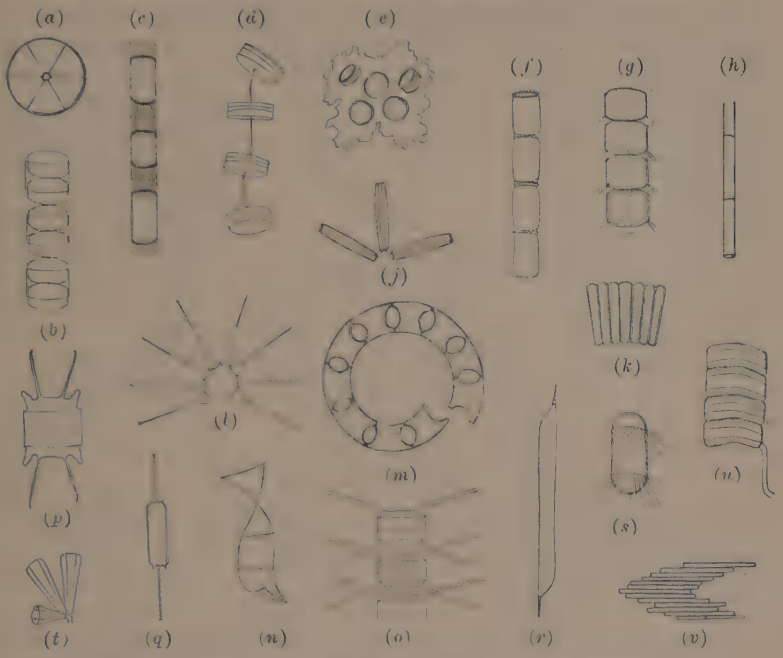


FIG. 3.—Diagrams of typical planktonic diatoms. (*a*) *Actinoptychus*; (*b*) *Melosira*; (*c*) *Skelotonema*; (*d*) *Thalassiosira*, typical form; (*e*) *Thalassiosira* embedded in mucilage; (*f*) *Detonula*; (*g*) *Lauderia*; (*h*) *Leptocylindrus*; (*j*) *Thalassiothrix*; (*k*) *Fragilaria*; (*l*) *Asterionella*; (*m*) *Eucampia*; (*n*) *Streptotheca*; (*o*) *Chætoceros*; (*p*) *Biddulphia*; (*q*) *Ditylium*; (*r*) *Rhizosolenia*; (*s*) *Corethron*; (*t*) *Lycmophora*; (*u*) *Achnanthes*; (*v*) *Bacillaria* (G. E. W.).

NUTRITION.

Nutrition is **holophytic,** that is to say, the diatom feeds as a typical plant and obtains its nourishment from dissolved gases and simple salts. With extremely few exceptions (*e.g.* in the saprophytic forms, omitted here as not planktonic, although often present in the sea) the cytoplasm contains chromatophores which themselves contain chlorophyll or some closely related

substance, yellow, golden brown or greenish brown, or, rarely, truly green. It is generally supposed that the brown pigment **diatomin** masks the other colours (West and Fritsch, 1927), and the usual tint is a greenish brown. By means of this colouring matter the diatom is able in the presence of sunlight to fix the carbon dioxide dissolved in the water and utilize the carbon so obtained in building up its complex food-stuffs, liberating oxygen in the process. This process is known as **photosynthesis.** The chemical changes in the open sea due to photosynthesis are chiefly to be ascribed to diatoms. These changes do not extend deeper than about 30 metres. In photosynthesis light is among the most important limiting factors, and the depth at which photosynthesis may be carried out must depend on the light intensity. Gran and Gaarder (1927), working in Oslo Fjord, which is probably far less transparent than the open sea, and using samples of sea-water rich in diatoms, found that photosynthesis was considerably less below than at the surface, and that at about 10 metres photosynthesis and respiration just balanced one another. Marshall and Orr (1928) used cultures of diatoms enclosed in glass-stoppered bottles, placed in wire cages in the sea and anchored to a buoy at various depths. They found that in inshore waters respiration and photosynthesis balanced at about 20 to 30 metres in summer, nearer the surface in winter. More photosynthesis takes place nearer the surface with increasing light up to about 2 or 3 metres. Above this the light is too strong; even in mid-winter the light is too strong at the surface. As we go further from land the depth at which maximum photosynthesis takes place increases.

There may be one or several chromatophores in each cell and there may be plate-like, disc-shaped, or large irregular masses. **Pyrenoids**—special reserve food bodies—occur sometimes in connexion with the chromatophores, and oil-globules are frequent. The large vacuoles containing oil or sap are nearly always, if not always, present. The oil stored in the cells is usually regarded as of more

importance than starch, although an analysis of the cell contents shows the amount of carbohydrate present to be large.

The chief salts used by the phytoplankton are nitrates, phosphates and silicates. Of these there is an ample supply in the sea, except at certain times, when nitrates and phosphates are scarce. Harvey (1926–1928) has shown that in the English Channel the nitrates are almost completely used up in the upper water layers during the outburst of diatom growth in the spring, to be re-formed later in large amounts. Matthews (1916–17) and Atkins (1923, '25, '26, '28) show the same for phosphates. Later on these salts are regenerated in the lower water layers by the decay of both animals and plants and by the excretion of animals. Measurement of phosphate content shows roughly an inverse ratio to the amount of phytoplankton.

Reproduction.

The commonest and best-known method of reproduction is asexual by cell division, the two valves separating and a new valve to each being formed before separation. **Karyokinesis,** or indirect cell division, has been shown to take place in several forms and is probably universal (Bergon, 1907, Ikari, 1923, Miquel, 1894, H. Péragallo, 1907, and others). The daughter-cell formed by the cell division is usually smaller than the parent, although in thin-walled forms there is a good deal of elasticity, and not much difference is seen eventually in the size of the cells. Cultures of *Nitzschia closterium* made by Allen and Nelson (1910) extending over two years showed little reduction in size. In thick-walled species, however, a diminution in size is continually going on. It is supposed that the main reason for **auxospore** formation is to bring the cells to a large size again, and this is probably the most important reason in those which are formed asexually. An auxospore is a large bladder-like mass of protoplasm, with a thin wall, formed from the parent

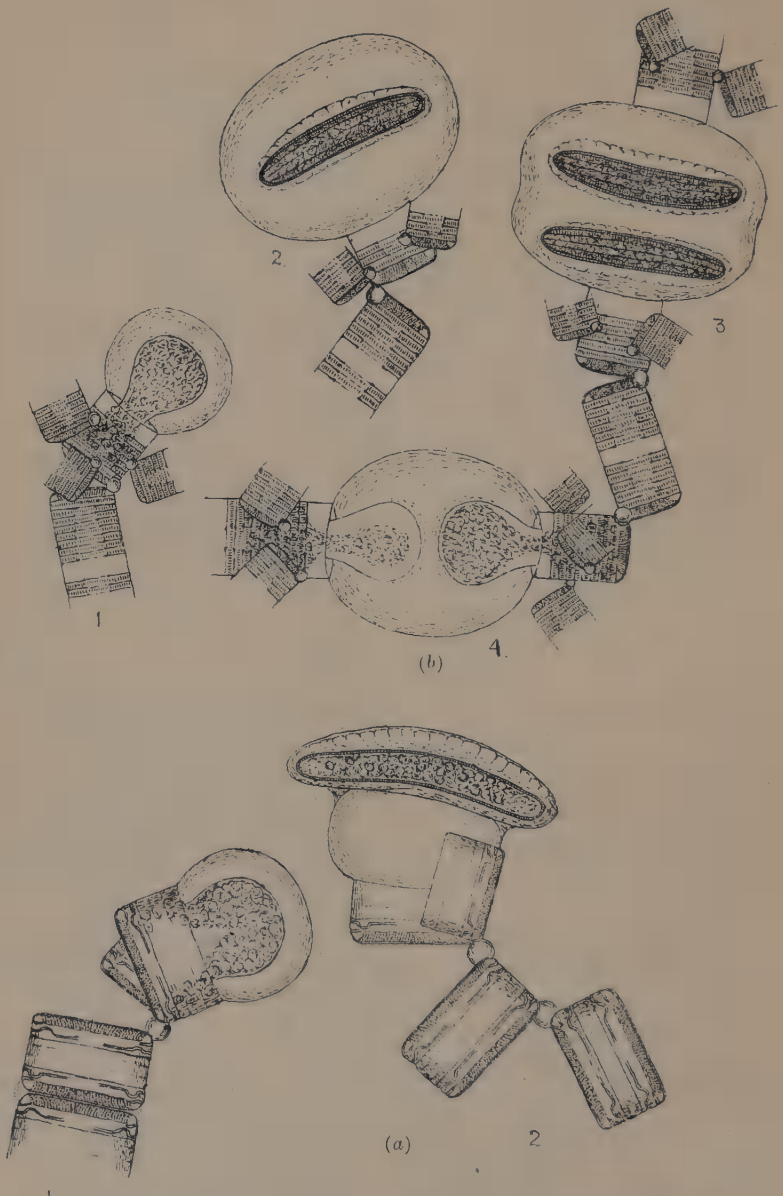


Fig. 4.—Auxospore formation in (*a*) *Grammatophora marina* Kütz.; (*b*) *Rhabdonema adriaticum* Kütz. (Ed. Milton). 1. Young sporangium and auxospore; 2. mature single sporangium and auxospore; 3. mature double sporangium and auxospores; 4. young double sporangium and auxospores.

cell, usually by the separation of the valves, the auxospore swelling out and forming inside it a new cell, or

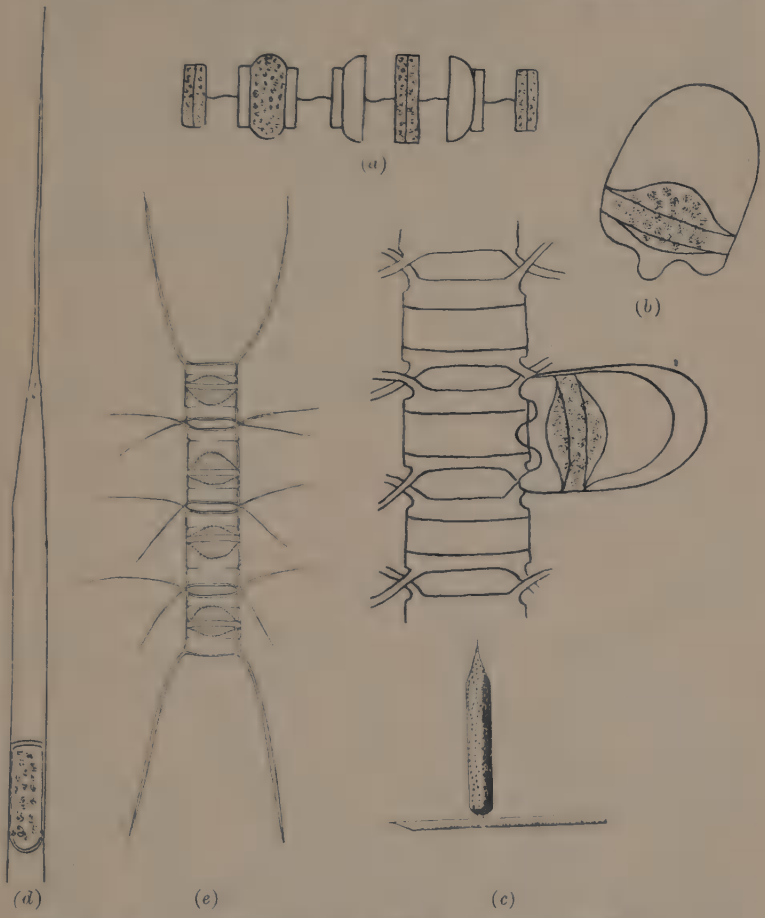


FIG. 5.—Auxospore formation in (*a*) *Thalassiosira gravida*, Plymouth (M. V. L.); (*b*) *Chætoceros Eibenii*, English Channel (M. V. L.), the auxospores containing resting spores; (*c*) *Rhizosolenia Shrubsolei*, after Meunier, 1915; resting spores in (*d*) *Rhizosolenia setigera* Rhos-on-Sea (M. V. L.); (*e*) *Chætoceros constrictus*, Plymouth (G. E. W.).

two new cells, which are usually larger than the parent (Figs. 4, 5). These are most often, if not always, asexual in the centricate forms and the probable reason

is to reach a large size, but in the pennate diatoms the auxospores may be formed sexually by conjugation, the contents of two cells and the fusion of nuclei being involved. Geitler (1928) describes conjugation, reduction of nuclei and gamete formation with auxospores in a species of *Nitzschia*. The two cells may be, and often are, of different sizes. Few detailed observations have been made on this point, but some observers have noted the fact that in certain forms small cells fix themselves to the larger cells prior to the formation of auxospores from the latter, and in some manner get rid of their cell contents. Mr. Ed. Milton, whose observations are unpublished, has drawn the two figures given here (Fig. 4) showing auxospore formation in *Rhabdonema* (already described by Smith, 1853–56, and Karsten, 1899) and *Grammatophora*. These show smaller cells, which he states are always present before auxospore formation. They have also been observed and figured by Buffham (1885) in *Rhabdonema*, and by others, but their significance is uncertain. Karsten (1899) describes a division of nuclei before the formation of an auxospore in *Rhabdonema*, one of the nuclear halves disappearing. The protoplasmic mass in which the auxospore is formed is sometimes known as the **sporangium.** Inside this the auxospore forms a membrane, the **perizonium**, composed of pectic substances and slightly silicified, and within this the new cell with its valves develops. In the ordinary asexual method the new cell is formed directly in the swollen mass of protoplasm which is itself known as the auxospore. In certain cases an auxospore may be developed from the girdle portion of the cell at right angles to its cell axis, and the product may be either a larger cell (in some species of *Rhizosolenia* and *Chætoceros*) or a true resting spore (certain species of *Chætoceros*) (Fig. 5).

Resting spores or **endocysts** with very thick walls and often provided with spines are formed in many of the centricate diatoms (Fig. 5). These may be formed without the intervention of auxospores within the

ordinary cell. This is their usual way of formation, although, as stated above, they may be formed in lateral auxospores. Only the neritic diatoms are known to form these resting spores, for with truly oceanic species the depth is apparently too great for them to be of use. Nevertheless they take a long time to sink, and many have been found at fairly great depths far out to sea. Ostenfeld (1913*a*), experimenting with resting spores, found that they lived many months and withstood much greater variations in temperature than the ordinary vegetative cells. Frequently in diatoms having both

FIG. 6.—Microspore formation in *Coscinodiscus*, after Pavillard 1914.

a spring and summer maximum resting spores are found at the end of the first, but not after the second maximum, the spores being formed to withstand the summer heat and remaining on or near the bottom until ready to develop again.

Swarm spores or **microspores** have been observed in a few diatoms, (Bergon, 1903*b*, 1907, Pavillard, 1914, Karsten, 1904, and others), but very little is known about them. Flagellated spores were seen by Bergon in *Biddulphia* and by Pavillard in *Coscinodiscus* (Fig. 6). Non-motile spores have been observed in several cases, but the development has not been followed further. It has been suggested that the spores are gametes, but

the evidence so far is apparently inadequate. Karsten (1924) summarizes our knowledge of microspores up to the present time. Schmidt (1923, '27, '28) also discusses them at some length.

Habits, Etc.

Planktonic diatoms float in those layers of water which are penetrated by the sunlight. Very few thrive below a depth of about 90 metres in our northern waters, although they have been found alive as deep as 200 metres. Bottom forms may be fixed or free. Many of those living on the bottom are fixed by one cell which may give rise to a chain. In this case portions of the chains frequently break off and become part of the plankton. Such forms are called **tychopelagic,** and may remain floating for some time although never reproducing in the plankton. Those forms which are dependent on the coast are sometimes called **meroplanktonic,** and those which are truly planktonic are called **holoplanktonic. Neritic** forms are those which have their origin near the coast and reproduce there, and **oceanic** forms are those which live and reproduce in the open sea. The neritic species, however, may often be found in the ocean, and oceanic species are often wafted near the coast. It is very difficult, if not impossible, to draw the line between neritic and oceanic species. Some diatoms prefer a high and some a low salinity. Many can live within a wide range. There are usually more diatoms near the shore than in the open sea. This is probably because there is more available food. There are more diatoms in cold than in warm regions. Littoral species are those which live exclusively near the shore. Estuarine and brackish-water forms are numerous, but with these we have little to do. Occasionally they come into the sea and may at times be important in the plankton. In these cases they are mentioned or described.

The movement of diatoms is extremely interesting, but difficult to understand, and the method by which

they move is still not exactly known. It is only those species which possess a true raphe which are capable of spontaneous movement, and these are usually not truly planktonic. The basis of the movement is the streaming of the cytoplasm through the raphe, thus putting the cell contents in direct contact with the water and setting up currents of streaming cytoplasm. It is not necessary for the cell to be in contact with a substratum, although this is frequently the case, for gliding, jerky and rolling movements may take place in a perfectly free diatom. A good short account of this movement and its probable mechanisms is given in West and Fritsch's 'British Freshwater Algæ,' 1927.

Diatoms are of the first importance as food in the sea. "The meadows of the sea" is the term given to the floating plant life almost universally present, and the greater part of this plant life is composed of diatoms. There may be enormous numbers present. Dr. Allen (1919) has estimated by his second method of diatom cultures that in an average sample of water from Plymouth Sound there must be a minimum of 464 organisms, most of which are diatoms, in a cubic centimetre. Lohmann (1908) has estimated 778,000,000 cells of *Skeletonema costatum* in 100 litres of water from Kiel. In the late winter and early spring in our area, and also in many other places, *e.g.* the Gulf of Maine (Bigelow, 1926), a large maximum of diatoms usually occurs, especially in coastal regions, a second maximum frequently presenting itself in late summer or autumn. In the summer months the genus *Rhizosolenia*, particularly the needle-like forms such as *R. alata*, *R. Shrubsolei* and *R. styliformis*, is present in enormous numbers, the genus *Biddulphia* occurring especially in the autumn, whilst in the winter there are fewer diatoms, although some are always there. The spring maximum is composed of many genera, including *Thalassiosira*, *Coscinodiscus*, *Chætoceros* and *Skeletonema* (Lohmann, 1908, Herdman, 1913–1922, Lebour, 1917, and many others).

It is often the case that bottom forms are common in the upper water layers. Owing to the vertical mixing occasioned by the surface water being cooled during the autumn and winter, these bottom forms are brought into the upper water layers, and the process is a continuous one until the upper layers begin to rise in temperature again in spring. Towards this mixing the action of the wind probably contributes somewhat in the absence of any density differences tending to oppose it. When once the diatoms have reached the upper layers it is probable that the greater viscosity of the colder water experienced during the winter is a factor in delaying their sinking again to the bottom.

Diatoms may vary considerably in winter and summer, and one species may look so different that several species might be thought to be present. Gran (1912) shows forms of *Chætoceros decipiens* from Spain with large apertures, this warm-water type corresponding to the summer form with thinner cell-wall and more slender structure, the surface larger and excess weight reduced, whilst those from Christiania were with smaller apertures, corresponding to the winter form.

The diatom flora of the area here described consists of Arctic, boreal and temperate species, boreal species being cold-water forms having a northern origin other than Arctic, temperate species being those between boreal and tropical. Tropical forms are occasionally found, *e. g.* certain species of *Chætoceros* or *Biddulphia*, sometimes taking up a permanent home, as in the case of *Biddulphia sinensis*, only known in these regions since about 1908 and now a permanent member of the plankton (Ostenfeld, 1908*b*). Some species have a range from Arctic to Antarctic waters, but the main Antarctic diatom flora (Mangin, 1915, 1922, Karsten, 1905, Van Heurck, 1909) is different from the Arctic, there being extremely few species which are purely bipolar and not occurring in between. The truly neritic species are almost all different in Arctic and Antarctic waters, and those species which are present in both are almost

entirely oceanic and may be found in waters between the two.

In studying planktonic diatoms and their distribution account must always be taken of the movements of the waters which they inhabit. *A planktonic diatom never remains in the same place.*

Parasites and Symbiotic Associations.

(Fig. 7.)

Even such small plants as diatoms are subject to infestation by parasites, and in many cases **symbiosis** occurs (the association of two organisms, animal or plant, for their mutual benefit, or at any rate for the benefit of one and not harmful to either). It is difficult to be sure that these associations are truly symbiotic in the case of diatoms, but it is certain that some forms are constantly found in association with other organisms.

True parasites are represented by the fungus *Olpidium* living in many species of diatoms (see Meunier, 1910, 1915, and others), also other fungi. The alga *Richelia intercellularis*, first described by Joh. Schmidt (1901), is known in and on the cells of *Rhizosolenia*, and the dinoflagellate *Paulseniella chætocerates* (Paulsen) Chatton on the bristles of *Chætoceros* was first described by Paulsen (1911) from the East Greenland Sea and named by Chatton *Paulseniella* (1920). This dinoflagellate is known on *C. borealis* and *C. decipiens*, the cells being fixed by small stalks inside the bristles and appearing as round prominences outside, dividing into two and four spores.

Epiphytes and **Epizoa** (plants or animals living on the outside of other plants and animals) are frequent. Thus we have the flagellates *Solenicola setigera* Pav. and *Bicœa mediterranea*, also *Vorticella oceanica* Zach. and others. *Solenicola setigera* on *Dactyliosolen mediterranea* has been known for many years (Gran, 1905, Mangin, 1913), but its true structure was only elucidated recently by Pavillard (1916*b*). This forms colonial

masses outside the cell-wall of the diatom, each individual flagellate having a long **flagellum** or whip-like hair. *Bicœa mediterranea* Pavillard (1916*b*) on *Skeleonema costatum*, *Nitzschia seriata*, *Cerataulina Bergonii*, *Chætoceros anastomosans*, *C. Lorenzianus* and *Thalassio-*

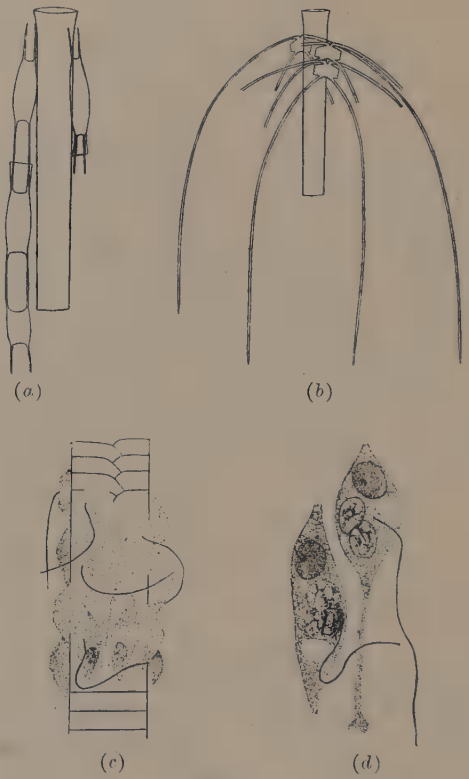


Fig. 7.

thrix Frauenfeldii is a flagellate with a vase-like case, six together adhering by a common disc, each with a separate stalk.

On the other hand we have diatoms themselves living on animals. Several live on Tintinnids, which are planktonic *Infusoria* with vase-like houses in which the individual cell may be completely retracted, and in

which it is fixed by a stalk, but when swimming the front part is protruded. Of these *Tintinnus lusus-undæ* Entz is associated with the diatoms *Hemiaulus Hauckii*

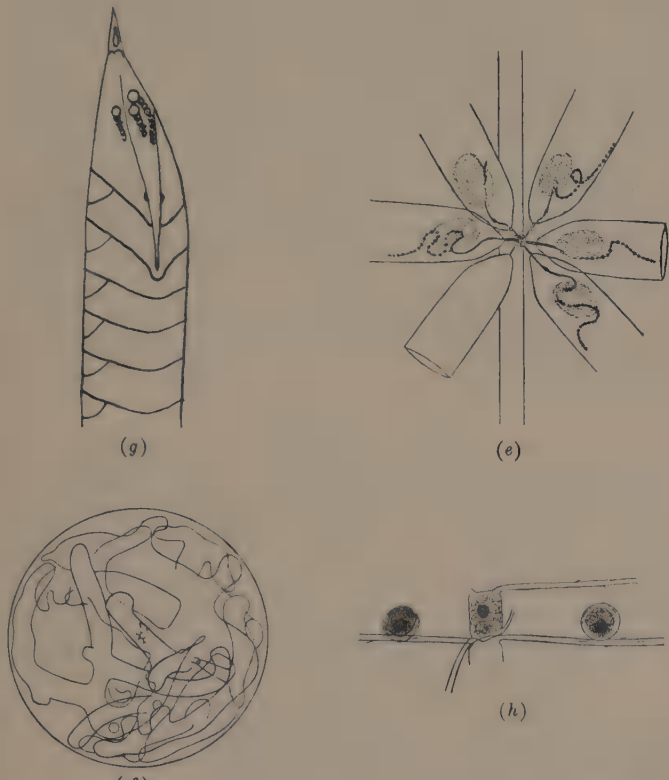


FIG. 7.—Epiphytes and parasites. (*a*) Association of *Hemiaulus* with *Tintinnus*; (*b*) of *Chætoceros* with *Tintinnus*; (*c*) *Solenicola setigera* on *Dactyliosolen*; (*d*) the same isolated; (*e*) *Bicœa mediterranea* on *Nitzschia*, after Pavillard, 1916; (*f*) *Coscinodiscus* infected by a mycelium, after Pavillard, 1914; (*g*) *Richelia intercellularis* in *Rhizosolenia*, after Pavillard, 1925; (*h*) *Paulseniella chætocerates* on *Chætoceros*, after Paulsen, 1911.

and *Chætoceros peruvianus*, whilst *T. inquilinus* O. F. Müller is associated with *Chætoceros Dadayi* and *C. tetrastichon* (Pavillard, 1916*a*, 1925, Famintzin, 1889,

Daday, 1887). The diatoms are always placed in regular and certain positions with regard to their hosts and in all probability protect them with their spines.

Other symbiotic organisms are described by Ostenfeld (1902, 1913*a*): *Amphorella borealis* Daday in the semilunar fissure of the valves of *Palmeria Hardmanniana* Greville, Karsten (1905–7), infusoria and fungi in diatoms and others. Lohmann (1917) has described from the high seas (Brazil Stream) a small Coccolithophore, *Pontosphæra sessilis* Lohmann, which lives fixed to the girdle of *Coscinodiscus*-like diatoms, *Brenneckella Lorenzi* Lohm. and *B. Kohli* Lohmann. These, however, have not been found in our area. Schröder (1914) gives a list of " Planktonepibionten " or plankton organisms, including several plankton diatoms, either serving as " guests " or " hosts."

Classification.

The classification adopted here is based on those of Schütt (1896), Karsten (1928), West (1916), West and Fritsch (1927) and Forti (1913) for the main large groups, but is somewhat altered by including in the Discoideæ some of the genera usually placed in the Solenoidæ, and in the creation of several families. In this way simplification is effected, and, in the writer's opinion, a more natural method is attained, although the centricate diatoms are extremely difficult to divide at all, as all seem to be closely related.

The main feature of the classification of diatoms is the division into two groups here regarded as orders, the first, the Centricæ or Centrales, containing the centricate or centric diatoms, having a concentric or radiating sculpture around a point, or points, without a raphe or pseudoraphe, and never capable of spontaneous movement; the second, the Pennatæ or Pennales, containing the pennate diatoms, having their sculpture arranged with relation to a longitudinal line, often with a raphe or pseudoraphe and to a large extent capable

of spontaneous movement. The first of these groups is by far the more important in the plankton, and it is chiefly the diatoms contained therein which are described here.

Three groups within the CENTRICÆ are usually recognized, the DISCOIDÆ with their valve sculpture arranged in relation to a central pole, the SOLENOIDÆ with their valve sculpture arranged in relation to an excentric pole, and the BIDDULPHIOIDÆ with their valve sculpture arranged in relation to two or more poles. Whilst most known centricate diatoms fall easily into their places in these three groups, there are some which are always difficult to place; such are the genera *Corethron*, *Guinardia* and *Bacteriastrum*, the first and second usually placed in the SOLENOIDÆ (although Schüssnig (1915) places *Guinardia* in the COSCINODISCACEÆ), the last in the BIDDULPHIOIDÆ. In the present classification they are all three placed in the DISCOIDÆ, somewhat enlarged to embrace certain cylindrical forms with circular section which appear to have more affinity with those usually placed in that group, although also having undoubted resemblances to those in the group in which they were originally included.

CLASSIFICATION.

Class DIATOMALES (=BACILLARIALES).

Order I. *CENTRICÆ* Schütt, 1896.

Group A. DISCOIDÆ Schütt, 1896.

Family 1. MELOSIRACEÆ Schröder, 1911.

Genus *Melosira* Agardh, 1824.
Paralia Heiberg, 1863.
Hyalodiscus Ehrenberg, 1845.

Family 2. COSCINODISCACEÆ Schröder, 1911.

Genus *Coscinodiscus* Ehrenberg, 1839.
Planktoniella Schütt, 1893*a*.
Actinoptychus Ehrenberg, 1843.
Asteromphalus Ehrenberg, 1844.
Actinocyclus Ehrenberg, 1839.
Eupodiscus Ehrenberg, 1839.
Euodia Bailey, Ralfs in Pritchard, 1861.

Family 3. THALASSIOSIRACEÆ n. fam.

Genus *Thalassiosira* Cleve, 1873*a*.
Coscinoscira Gran, 1900*b*.
Lauderia Cleve, 1897*a*.
Schröderella Pavillard, 1913.
Bacteriosira Gran, 1900*b*.

Family 4. SKELETONEMACEÆ n. fam.

Genus *Skeletonema* Greville, 1865.
Stephanopyxis Ehrenberg, 1844.
Detonula Schütt, 1893*b*.

Family 5. LEPTOCYLINDRACEÆ n. fam.

Genus *Dactyliosolen* Castracane, 1886.
Leptocylindrus Cleve, 1889.
Guinardia H. Péragallo, 1892.

Family 6. CORETHRONACEÆ n. fam.

Genus *Corethron* Castracane, 1886.

Family 7. BACTERIASTRACEÆ n. fam.

Genus *Bacteriastrum* Shadbolt, 1854.

Group B. SOLENOIDÆ Schütt, 1896.

Family 1. RHIZOSOLENIACEÆ Schröder, 1911.

Genus *Rhizosolenia* (Ehrenberg) Brightwell, 1858*a*.

Group C. BIDDULPHIOIDÆ Schütt, 1896.

Family 1. CHÆTOCERACEÆ Schröder, 1911.

Genus *Chætoceros* Ehrenberg, 1844.

Family 2. BIDDULPHIACEÆ n. fam.

Genus *Biddulphia* Gray, 1832.
Bellarochia Van Heurck, 1880–1885.
Hemiaulus Ehrenberg, 1844.
Cerataulus Ehrenberg, 1843.
Cerataulina H. Péragallo, 1892.
Lithodesmium Ehrenberg, 1841.
Ditylium L. Bailey, 1862.

Family 3. EUCAMPIACEÆ Schröder, 1911.

Genus *Eucampia* Ehrenberg, 1839.
Climacodium Grunow, 1868.
Streptotheca Shrubsole, 1890.

Order II. *PENNATÆ* Schütt, 1896.

Family 1. FRAGILARIACEÆ Schröder, 1911.

Genus *Fragilaria* Lyngbye, 1819.
Asterionella Hassal, 1845.
Thalassiothrix Cleve and Grunow, 1880.

Family 2. TABELLARIACEÆ West, 1927.

Genus *Striatella* Agardh, 1832.
Grammatophora Ehrenberg, 1839.
Rhabdonema Kützing, 1844.
Lycmophora Agardh, 1832.

Family 3. ACHNANTHACEÆ West, 1927.

Genus *Achnanthes* Bory, 1822.

Family 4. NAVICULACEÆ West, 1927.

Genus *Navicula* Bory, 1822.
Gyrosigma Hassal, 1845.
Amphiprora Ehrenberg, 1843.

Family 5. NITZSCHIACEÆ Schröder, 1911.

Genus *Bacillaria* Gmelin, W. Smith, 1856.
Nitzschia Hassal, 1845.

Family 6. SURIRELLACEÆ West, 1927.

Genus *Surirella* Turpin, 1827.
Campylodiscus Ehrenberg, 1841.

Class DIATOMALES.

Unicellular algæ having an outer skeleton composed of pectin impregnated with silica formed of two valves joined by a girdle.

Order *CENTRICÆ* Schütt, 1896.

Valves with a concentric or radiating sculpture around a point or points, central or lateral, never arranged in relation to a middle line, without raphe or pseudoraphe, and not capable of spontaneous movement. Auxospores frequently formed. Motile spores also observed.

Group DISCOIDÆ Schütt, 1896.

Cells disc-shaped or cylindrical. Cross-section circular (except in *Euodia*). Valve sculpture arranged in relation to a central pole.

Family Melosiraceæ Schröder, 1911.

Cells subspherical or shortly cylindrical, in chains, the bottom cell fixed by a glutinous pad of cytoplasm to a substratum. Pieces of the chains or single cells often break off and come into the plankton proper, never, however, reproducing there. Valve rounded. Intercalary bands often sculptured. Neritic or littoral.

Genus **MELOSIRA** Agardh, 1824.

Cells cylindrical or circular, usually finely sculptured with small dots, united in bead-like chains by the centres of the valves. Numerous small chromatophores in each cell. All living near the coast and not truly planktonic, probably naturally living near or on the bottom, frequently, however, occurring in coastal

plankton. Auxospores formed by the ordinary cells parting at their girdles. Resting spores also formed.

Species: *Melosira Borreri* Greville, *M. hyperborea* (Grun.).

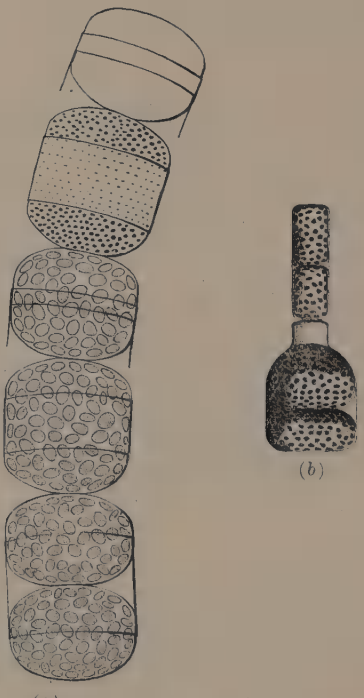


FIG. 8.—*Melosira Borreri* Grev. (*a*) 38μ across, Plymouth (G. E. W.); (*b*) auxospore formation, after Meunier, 1915.

Melosira Borreri Greville, 1833.

(Fig. 8.)

Gran, Nordisches Plankton, p. 12.

Valves strongly convex, punctated. Girdle with fine puncta arranged in rows. Cell 25 to 60μ across. End cell usually fixed, but in the plankton free strands occur which have been detached from their natural

surroundings. Usually in a state of division so that two cells in the process of formation are surrounded by the girdle bands which have not yet separated. Auxospores frequent. The cell opens in the centre by the girdle bands separating, and a large globular mass, the auxospore, emerges which eventually forms a similar but much larger cell. Littoral, tychopelagic. Likes a low salinity.

Distribution.—Widely distributed along the coast from the northern parts of the North Sea to the Channel and west coast of France. Known from Danish and Norwegian seas and Baltic, and both the European and American sides of the Atlantic. The commonest species of this genus in the British Isles.

Melosira hyperborea (Grun. in Van Heurck's Synopsis, 1880–85).

(Pl. I, fig. 1.)

Gran, Nordisches Plankton, p. 13.

Cell circular or elliptical. Cell-wall thin without visible sculpture. Keel at the top of the valve. Chains formed by the juxtaposition of the keels. Diameter 14–30μ. Resting spores in the chains, usually two together, with thick walls with a crumpled net-like thickening outside (Gran). Neritic. Arctic.

Distribution.—In masses in the Arctic seas, near the coast in Polar regions. In winter in the Baltic. Very abundant among the Polar ice-floes. Gran (1900*c*) found the resting spores among the Polar ice, and Ostenfeld (1910) found them in the East Greenland seas, where the species is very common. Probably winters as resting spores frozen in the ice.

Other species described by Gran ('Nordisches Plankton,' pp. 12, 13) are *Melosira Juergensenii* Ag., much like *M. Borreri*, but smaller and narrower, littoral on the N. European coasts, *Melosira nummuloides* (Dillw.), with keeled valves, littoral on the coasts of N. Europe and

America. These may occur in the plankton. He also mentions as very rare in the plankton *M. Westii* W. Sm., littoral, and the freshwater species *M. granulata* (Ehr.) and *M. distans* (Ehr.). The following brackish and freshwater forms are recorded by the International Fisheries Investigations: *M. crenulata* Kütz., *M. italica* Kütz., *M. solida* Gran. Meunier (1910) records from the Kara Sea *M. varians* Agardh, a freshwater species. *Cyclotella meneghiana* (K.), a freshwater species, is probably closely related to *Melosira*.

Genus **PARALIA** Heiberg, 1863.

Short cylindrical cells, constricted at each end, firmly united by their valve surfaces into long straight chains. Valve surface with radial puncta. Cell-wall ornamented with a regular coarse network of more or less hexagonal markings. Chromatophores numerous. Auxospores known, formed as in *Melosira*.

Species : *Paralia sulcata* (Ehr.).

Paralia sulcata (Ehr.), 1839.

(Fig. 9.)

Gran, Nordisches Plankton, p. 14.

Cells disc-shaped. One girdle band usually covering the halves of two cells, 15–45μ across. Neritic and littoral, tychopelagic. Meunier (1915) figures the auxospores. Although a coastal diatom, it may occur far from land, and although in reality a bottom form, not reproducing in the plankton, with, presumably, a fixed basal cell, yet it may be regarded as a true member of the plankton, and forms one of the chief foods of many small planktonic animals as well as bottom species. It is one of those diatoms which is fundamentally important as food material. It is most frequently observed in the plankton in the winter. Ostenfeld (1913*a*) regards its predominance in winter as due to rough weather, which brings it up from the bottom, the

viscosity of the water at that time keeping it in the plankton. It is perhaps more easily explained by the vertical mixing of the water in winter due to the cooling of the upper layers (see above, p. 16). Likes a high salinity. A very widely distributed species known from the Arctic seas to the English Channel, North Sea, Baltic,

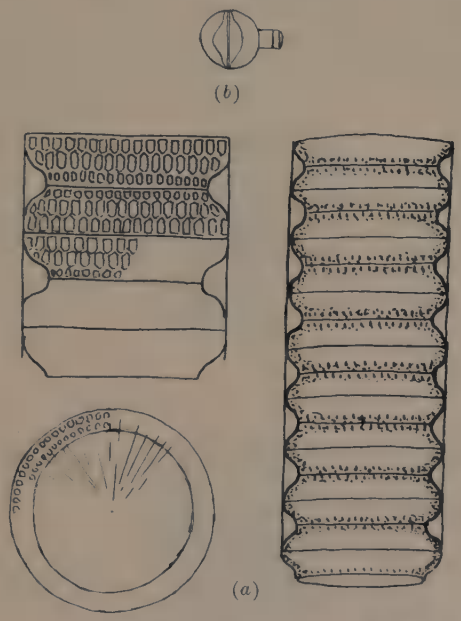


FIG. 9.—*Paralia sulcata* (Ehr.). (*a*) 36μ across, Plymouth (M. V. L.); (*b*) auxospore, after Meunier, 1915.

Skaggerak, Danish and Norwegian seas, Finland, American side of Atlantic, Mediterranean, west coast of France.

Genus **HYALODISCUS** (Ehr.), 1845.

Cells single or in short chains, shortly cylindrical. Valves rounded, finely punctate with radiating puncta, centre different from the surrounding part, provided with pores for the secretion of mucus for attachment

by a slimy pad to a substratum. Often floating freely in the plankton.

Species : *Hyalodiscus stelliger* Bailey.

Hyalodiscus stelliger Bailey, 1855.

(Figs. 10, 11.)

Gran, Nordisches Plankton, p. 26.

Valves strongly curved. Central part well differentiated. Puncta radiating outwards. Many narrow

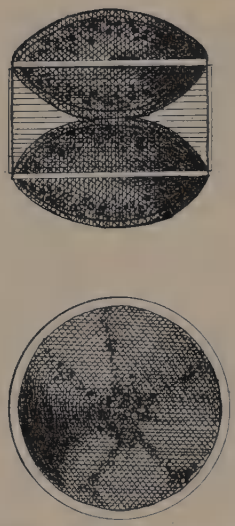
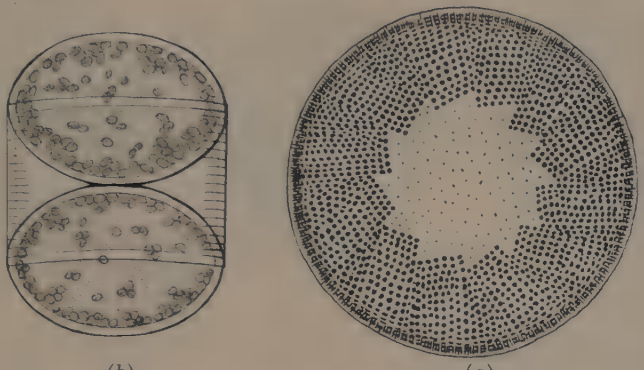


Fig. 10.—*Hyalodiscus stelliger* Bail., 65μ across, valve and girdle view, Plymouth (G. E. W.).

ring-like intercalary bands. Diameter 30–85μ. Neritic. This is, like *Paralia*, an important food form. It also lives on the bottom with one valve attached, but frequently occurs free in the plankton, tychopelagic, chiefly in winter, not reproducing there. The same remarks given for *Paralia* as to occurrence apply to this species. Likes a high salinity.

Distribution.—All parts of the North Sea, Sea of Kara and Barents Sea, Norwegian and Danish seas,

Skaggerak (rare in Baltic), Finland, English Channel, Flemish seas, all parts of the British Isles, Mediterranean, Atlantic coasts of America.



(*b*) (*a*)

Fig. 11.—*Hyalodiscus stelliger* Bail. (*a*) Showing valve sculpture (M. V. L.); (*b*) girdle view showing chromatophores (G. E. W.).

Family Coscinodiscaceæ Schröder, 1911 (restricted).

Cells disc-shaped, (except *Euodia*, which is triangular), solitary. Intercalary bands, if present, usually without sculpture. Marginal spinulæ and apicules (1 or 2) present or absent.

Genus **COSCINODISCUS** Ehr., 1839. (Fig. 12.)

Cells simple discs, without large knobs or processes. Valve sculpture hexagonal meshes or fine round puncta, or areoles arranged in different ways. Marginal spinulæ present or absent. Apicules (1 or 2) present or absent; if two are present they are placed asymmetrically at an angle of more than 90° and less than 180° on the margin. Girdle a single band to each valve, or with one or more collar-like intercalary bands. Chromatophores numerous small plates. Nucleus at or near the centre, or suspended

in the centre of the cell by strands of cytoplasm. Auxospores formed by the separation of the valves, a large bladder-like mass of protoplasm coming from one end.

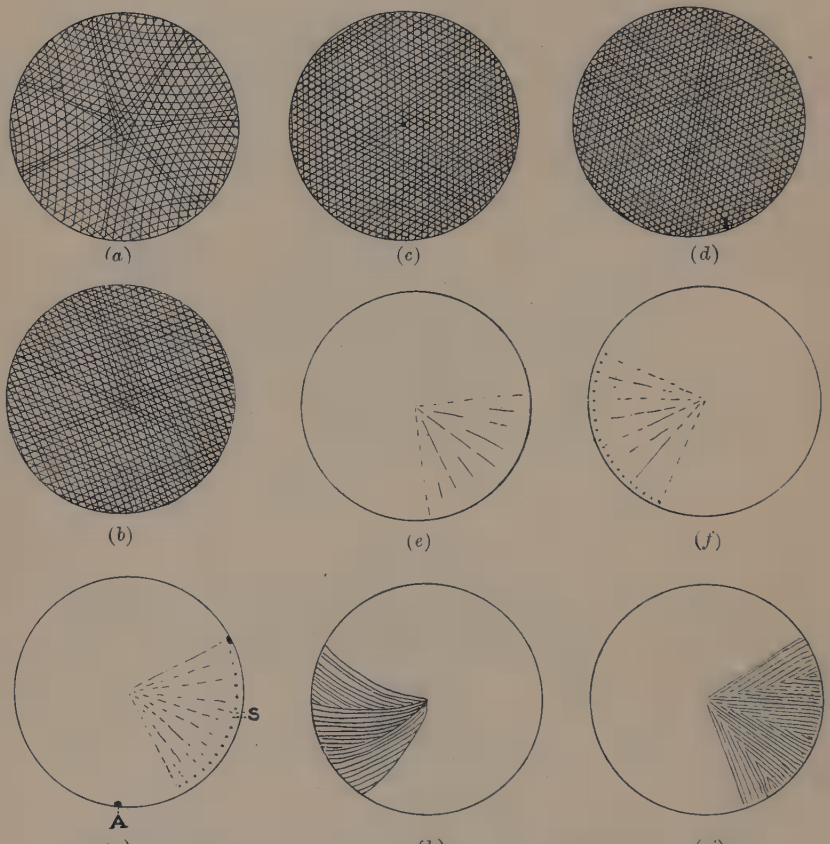


FIG. 12.—Diagram showing the plan of the chief sculpturings in *Coscinodiscus*. (*a*) *C. excentricus*; (*b*) *C. lineatus*; (*c*) *C. nodulifer*; (*d*) *C. leptopus*; (*e*) *C. radiatus*; (*f*) radiate type without apicules; (*g*) radiate type with apicules (*s.* = spinula, *a.* = apicule); (*h*) *C. curvatulus* type; (*j*) *C. subtilis* type (M. V. L.). The spinulæ have only been indicated in (*f*) and (*g*).

Many species are truly planktonic, others are bottom forms occasionally entering the plankton, and many more are heavy and truly bottom forms.

The genus is usually divided up according to the valve sculpture into four groups :

I. Excentrici, or excentric forms with the meshes or areoles not radiating from the centre.

II. Radiati, or truly radiate forms with the meshes or areoles radiating simply from the centre and not divided up into sectors.

III. Fasciculati, or fasciculated forms, with the meshes or areoles divided up into bundles or **Fasciculi** forming sectors.

IV. Stellares, having a star-like cluster of small knobs in the centre, the sculpture otherwise extremely fine.

Any of these may have spinulæ and one or two apicules or may have none, or they may have spinulæ without apicules. The radiate forms with apicules usually have a more or less pronounced rosette of areoles in the centre, but this may be absent, and a single cell may have a rosette on one valve and none on the other.

The importance of the spinulæ and apicules is undoubted, as pointed out by Ostenfeld (1908*a*, 1910, 1913*a*), but they are often difficult to see except by special methods of preparation. It is therefore important to take into consideration the shape and general character of the cell as much as possible, in order that a plankton worker may place the species, approximately at least, without resorting to detailed methods, except in special cases. The valves may be perfectly flat, slightly rounded, much rounded, rounded but flat or depressed in the centre, and the cell may be so low that it is coin-shaped, or moderately high or nearly as high as broad, or may be higher on one side than on the other.

Division of the Genus.

Many have tried to divide up the genus to facilitate the recognition of the species and to show their relationships. Chief among the more recent workers are Gran

('Nordisches Plankton'), Jörgensen (1905*a*), Ostenfeld (1908*a*, 1910, 1913*a*), and Pavillard (1924*a*, 1925).

We may now divide the genus up as follows:

Group I. Excentrici.

Meshes not radiating from the centre; valves flat.

A. Lines of areoles or meshes curved; spinulæ present *Coscinodiscus excentricus.*

B. Lines of areoles or meshes straight, spinulæ present or absent. One apicule present or absent. Central nodule present or absent.

1. Spinulæ and apicule absent, no central nodule *Coscinodiscus lineatus.*

2. Spinulæ and one apicule present; no central nodule . . . . *Coscinodiscus leptopus.*

3. Spinulæ present; no apicule; central nodule present . . . . *Coscinodiscus nodulifer.*

Group II. Radiati.

Meshes or areoles radiating from the centre, not divided up into sectors.

A. No spinulæ, no apicules. No conspicuous central rosette. Valves flat . . *Coscinodiscus radiatus.*

B. (*Biapiculati* of Ostenfeld.) Spinulæ present. Two apicules, placed asymmetrically at an angle of more than 90° and less than 120°. Valves rounded.

1. Coarse meshes or areoles, central rosette conspicuous or not, sometimes absent, cell always symmetrical. No granules scattered on valve.

* Sculpture coarse. No specialized central rosette. Apicules very large. Valve plano-convex in side view *Coscinodiscus commutatus.*

** Sculpture coarse, rosette more or less specialized, apicules fairly large.

° Rosette usually not much specialized. Valve in side-view plano-convex. *Coscinodiscus sub-bulliens.*

°° Rosette usually very conspicuous. Valve in side view evenly rounded without median flattening *Coscinodiscus centralis.*

2. Fine meshes or areoles. Central rosette usually fairly conspicuous; no granules scattered on valve. Apicules small. Bundles of meshes crossing the main radiate meshes. Cell may be more or less asymmetrical. Girdle with or without intercalary bands.

* Cell symmetrical or slightly asymmetrical, usually the breadth more than two-thirds of the height. Many intercalary bands.
Coscinodiscus concinnus.

** Cell much higher on one side than on the other; no intercalary bands
Coscinodiscus Granii.

3. Coarse meshes or areoles. Granules scattered on valve surface . . *Coscinodiscus Pavillardi.*

In addition to these divisions of the Radiati there is apparently another having spinulæ but no apicules. This includes *C. Thori* and *C. alboranii* of Pavillard, but there do not appear to be any in our area.

Group III. Fasciculati.

Meshes or areoles in sectors; the sectors curved or straight. Spinulæ and one or two apicules present or absent. Valve usually more or less flat; girdle not known in all forms.

A. Rows of meshes or areoles in a sector parallel to the main radius . . *Coscinodiscus curvatulus.*

B. Rows of meshes or areoles in a sector running parallel to the middle radius of the sector.

1. No spinulæ, no apicules . *Coscinodiscus Kutzingi.*

2. Spinulæ present. Usually cross-bundles of areoles mark the original sculpture
Coscinodiscus subtilis and allies.

Group IV. Stellares.

With a cluster of nodules in the centre of the valve. Valve sculpture very fine . . *Coscinodiscus stellaris.*

In addition to these four groups there are some little-known forms described which have no regular meshes, but are dotted all over with rounded areoles or small points. In these are included *Coscinodiscus marginatus* and *C. nitidus*. The former may, however, really belong to *C. radiatus*.

Group I. EXCENTRICI.

Meshes not radiating from the centre, valves flat.

Coscinodiscus excentricus Ehr., 1839.

(Fig. 13.)

Gran, Nordisches Plankton, p. 29.

Cell disc-shaped. Valves flat with narrow margins having spinulæ arranged in an irregular circle. Sculpture hexagonal meshes arranged in slightly curved,

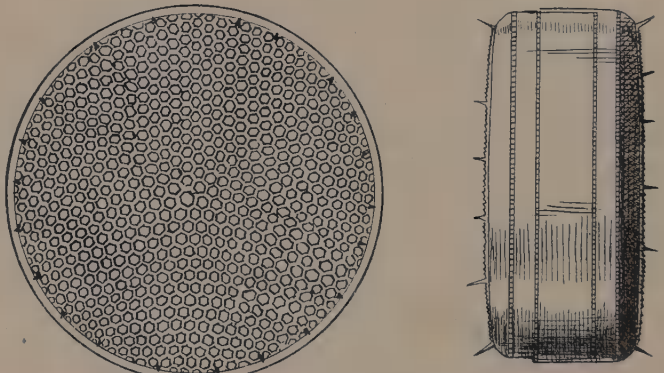


Fig. 13.—*Coscinodiscus excentricus* Ehr., 70μ across, Plymouth (G. E. W.).

nearly parallel rows, based on arrangement of seven divisions, the centre usually having a central mesh with seven meshes radiating from it. Girdle zone with a collar-like intercalary band and a ring-like girdle in each valve. Edges binding the different parts of the cell-wall thick and finely punctate. Diameter 50–90μ. Oceanic, but often occurring near the coast.

Distribution.—World-wide. North Sea, North and South Norwegian Seas, Danish seas, Baltic, Skaggerak, Finland, North Atlantic, English Channel, Mediterranean, Arctic and Antarctic, Atlantic and Pacific America.

The same valve sculpture is found in *Thalassiosira decipiens* and in *Planktoniella sol;* Péragallo (1897–1908)

therefore regards these as belonging to the same species. It is difficult to separate single cells of *Thalassiosira decipiens* from this species, but Ostenfeld (1908*a*) has shown that they do differ, *T. decipiens* having a rounded valve and curved spinulæ in the form of fairly long spines; *Planktoniella sol* is easy to separate by its broad membranous margin. There seems no reason to regard either of these as synonymous with *C. excentricus*. Karsten's (1905) *C. excentricus* from the Antarctic has the valve structure based on six sectors instead of seven, which latter is the usual one in these regions. His may be a different species. Seven is the typical one given by Jörgensen (1905*a*), and this agrees with the Channel form.

Coscinodiscus lineatus Ehr., 1839.

(Fig. 14.)

Gran, Nordisches Plankton, p. 30.

Cell of the same shape as *C. excentricus*, but with the meshes in straight lines instead of curves, based on six

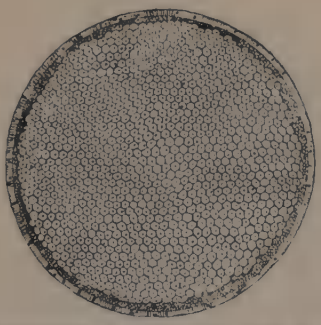


Fig. 14.—*Coscinodiscus lineatus* Ehr., after H. Van Heurck.

sectors. The meshes or areoles smaller at the margin. Small spinulæ round the margin. Diameter 50–60μ. Neritic. Probably not a truly planktonic species.

Distribution.—Faroes, Davis Strait, North Atlantic, Atlantic and Pacific America. Recorded by Karsten from the Antarctic.

Meunier (1915) regards this merely as a form of *C. excentricus*. Gran (1905) separates it, and rightly, regarding it as the true species described by Van Heurck (1880). Péragallo (1897–1908) also regards it as distinct. It has probably been much confused with several other species, including *C. leptopus* and *C. nodulifer*. Péragallo regards it as identical with *Coscinoscira polychorda*.

Coscinodiscus leptopus Grunow (Van Heurck, 1880–85).

(Pl. I, fig. 2*a*.)

Pavillard, 1925, p. 10.

Cells like *C. lineatus*, but with one long apicule besides the row of small spinulæ. Neritic.

Distribution.—French coast. Stomachs of salps from the Bay of Biscay. Norwegian coast. Atlantic and Pacific coasts of America.

Coscinodiscus nodulifer Janisch (A. Schmidt, 1875).

(Pl. I, fig. 2*b*.)

Pavillard, 1925, p. 11.

Cell like *C. lineatus*, but with a conspicuous nodule in the centre of the valve. Sculpture very strong. This species and *C. leptopus* are both heavy species, regarded by Forti (1922) as **benthonic** (inhabiting the lower water layers or bottom). They are, however, sometimes true members of the plankton. Neritic.

Distribution.—North Atlantic, Mediterranean, also Arabian and Indian Seas, Pacific American coast.

Group II. RADIATI.

Meshes or areoles radiating from the centre, not divided up into sectors.

A. Without central rosette, the meshes being the same in the centre as elsewhere. No spinulæ, no apicules.

Coscinodiscus radiatus Ehr., 1839.

(Fig. 15.)

Gran, Nordisches Plankton, p. 31.

Cells thin, coin-shaped discs. Valves flat or very slightly curved. No spinulæ. No apicules. Sculpture coarse and strong meshes about the same size from centre to margin, only distinctly smaller at the extreme edge. Girdle zone quite low. No intercalary bands. Diameter 30–120μ. Usually considered an oceanic species, but capable of living and reproducing in coastal waters as well as in the ocean.

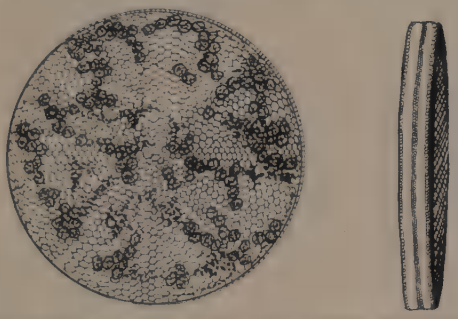


Fig. 15.—*Coscinodiscus radiatus* Ehr., 95μ across, Plymouth (G. E. W.).

Distribution.—Ubiquitous. In temperate seas very well distributed. Arctic seas to North Atlantic coasts, North Sea, Baltic, English Channel, Irish Sea, coasts of France, Mediterranean, Antarctic, American Atlantic and Pacific coasts.

B. Spinulæ present, two apicules placed asymmetrically at an angle of more than 90° and less than 120°. Valves rounded. Central rosette usually present, but may or may not be conspicuous.

Coscinodiscus centralis Ehr., 1839.

(Figs. 16*a*, *b*, 17*b*, 18*b*.)

Gran, Nordisches Plankton, p. 33.

Valves convex, not flattened in the centre. Strong radial sculpture with areoles not quite so coarse as in

C. sub-bulliens. Central meshes in a quite distinct rosette, the meshes from the centre gradually decreasing in size. Girdle with several intercalary bands. Marginal spinulæ small and closely set, 5–6 rows of areoles between them. Apicules conspicuous but rather small, situated at an angle of not much over 90°. Cells rather larger than *C. sub-bulliens*, diameter 120–300μ. Oceanic. Temperate species, widely distributed.

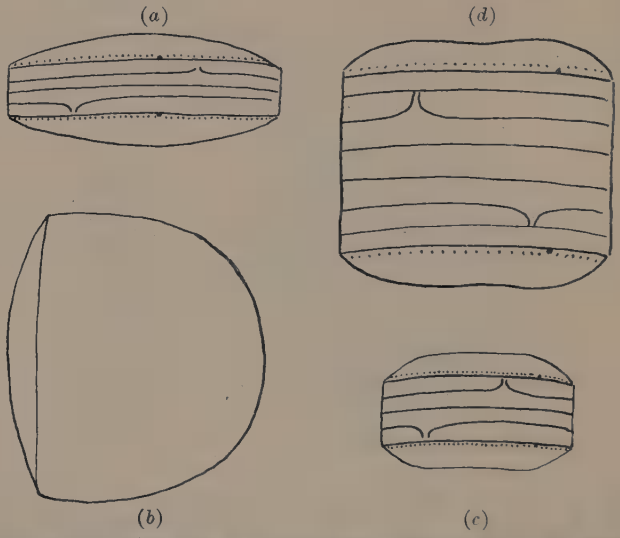
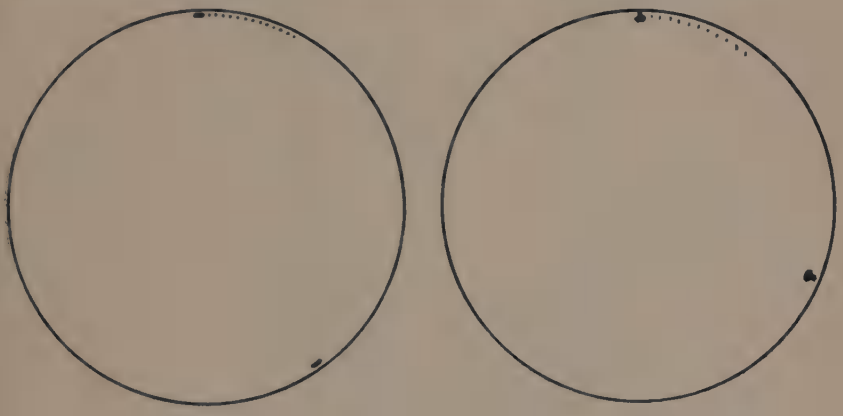


FIG. 16.—(*a*) Girdle view of *Coscinodiscus centralis* Ehr.; (*b*) auxospore formation in same; (*c*) girdle view of *Coscinodiscus sub-bulliens* Jörg.; (*d*) of *Coscinodiscus concinnus* W. Sm. (M. V. L.). *a, b, c*, from North Atlantic "Scotia" material, *d* from Plymouth. All drawn to scale.

Distribution.—North Atlantic, Davis Strait, Finland, North Sea, Skaggerak, Baltic, Mediterranean, Adriatic, Atlantic and Pacific America.

Auxospores found in Northern Atlantic "Scotia" material, similar to those described by Pavillard (1914) in a species called by him *C. oculus-iridis*. Later (1925) he apparently regards it as *C. centralis*. The cell outline (girdle view) is, however, different from the northern *C. centralis*, being more flattened.

This species, with *C. sub-bulliens* and *C. concinnus*, were the products of the splitting up of *C. oculus-iridis* by Gran (1905). Forti (1922) shows that the name *oculus-iridis* should only be used for the fossil species. *C. sub-bulliens* and *C. centralis* are closely related and regarded by some workers as belonging to the same species. *C. sub-bulliens* was originally described by Jörgensen as having no spinulæ nor apicules, and he is followed by Gran. Ostenfeld (1910) discovered both to



(*a*) (*b*)

Fig. 17.—Diagram of (*a*) *Coscinodiscus sub-bulliens*, 200μ across, and (*b*) *C. centralis*, 250μ across, showing spinulæ and apicules (M. V. L.).

be present, and he has kindly described the two forms for me in which they are shown to be quite distinct species. The descriptions here given are based on his distinctions.

Coscinodiscus sub-bulliens Jörgensen, 1905*a* (emended). (Figs. 16*c*, 17*a*, 18*a*.)

Gran, Nordisches Plankton, p. 32.

Usually smaller than *C. centralis*, valves thicker, plano-convex, areolation coarse, central rosette more or less indistinct. Girdle with only 1–2 intercalary bands.

Spinulæ very small, 3–4 rows of areoles between them; the two apicules small, their distance much more than 90°, approaching 180°. Diameter 65–150μ. Boreal oceanic form.

Distribution.—More northerly than *C. centralis*, not reaching the Mediterranean. Known from the English

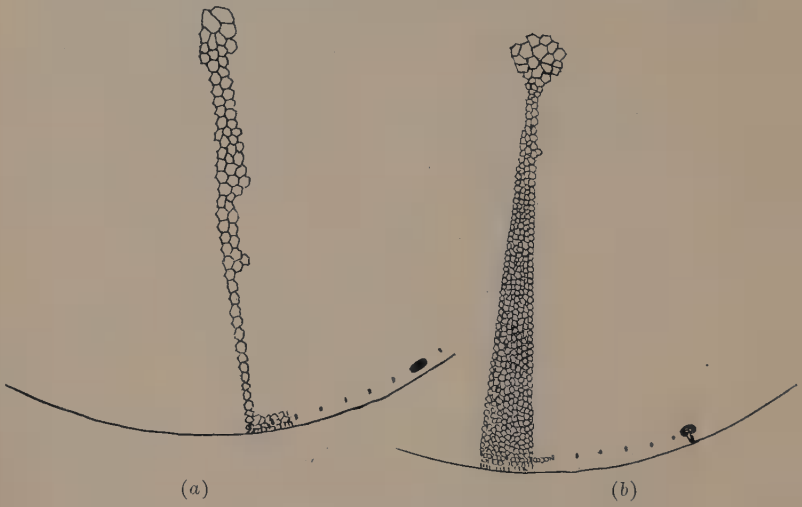


FIG. 18.—Portions of the same showing valve sculpture. (*a*) *C. subbulliens*, (*b*) *C. centralis* (M. V. L.).

Channel, North Sea, Northern Atlantic, Norway, Finland; recorded from San Diego, California. Probably often mixed up with *C. centralis*.

Coscinodiscus commutatus Grunow, 1884.

(Pl. I, fig. 3.)

Ostenfeld, 1915, p. 15.

Cell medium-sized, plano-convex. Valves with coarse sculpture, without well-differentiated central rosette. Small marginal spinulæ present. Two very large apicules sticking out from the valve. Brackish water form.

Distribution.—Zuider Zee, Baltic.

Coscinodiscus concinnus W. Sm., 1856.

(Fig. 16*d*, 19.)

Gran, Nordisches Plankton, p. 33.

Large cells, flattened at the centre, long, the length usually more than three-quarters of the breadth. Some-

Fig. 19.—*Coscinodiscus concinnus* W. Sm., 300μ across, Plymouth, (M. V. L.).

times slightly higher on one side than on the other. Sculpture very fine, radial, with central meshes large, but often not conspicuous, the others very fine, diminishing

in size towards the margin. Curved rows of meshes cross the radial rows, giving an irregular effect. Inside the margin a row of distinct but small spinulæ from which spring fine radial ribs. Two small apicules placed wide apart. Girdle with many intercalary bands. Diameter 150–450μ. Temperate neritic cold water form, liking a high salinity.

Distribution.—Centrally in North Sea, in great quantity in early spring, Finland, Irish Sea, English Channel, West Coast of France, Mediterranean, Atlantic and Pacific America.

Coscinodiscus Granii Gough, 1905.

(Figs. 20, 21.)

Gran, Nordisches Plankton, pp. 34–35.

Valves rounded, the highest point excentric. Cell double as high on one side as on the other. Valve

FIG. 20.—*Coscinodiscus Granii*, 50μ across, valve and girdle view showing chromatophores (valve sculpture not shown), Plymouth (G. E. W.).

sculpture as in *C. concinnus*. Girdle formed from the two similar girdle bands. No intercalary bands. Diameter 50–150μ. Neritic.

Distribution.—Norwegian Seas, North Sea, Danish seas (?), Skaggerak (?), Baltic, Irish Sea, English Channel. Often with *C. concinnus*. Recorded from San Diego, California.

The Danish form may be a different species according to Ostenfeld (1913*a*). *C. Granii* is sometimes regarded (Péragallo and others) as identical with *C. concinnus*. It is, however, quite distinct, being always much more irregular in shape and having no intercalary bands.

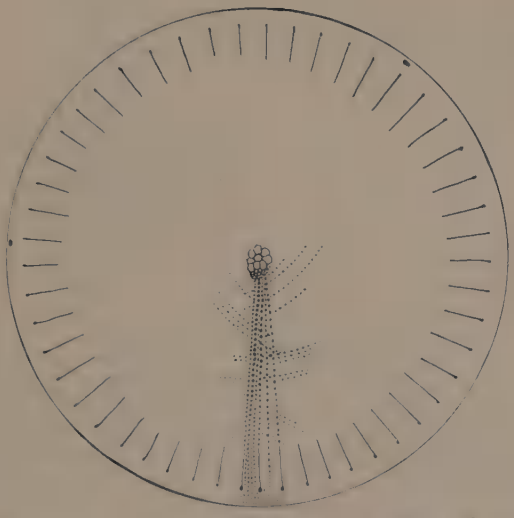


Fig. 21.—*Coscinodiscus Granii*, 150μ across, showing valve sculpture, Plymouth (M. V. L.).

Coscinodiscus Pavillardii Forti, 1922.

(Fig. 22.)

Forti, 1922 ; Pavillard, 1925, p. 14.

Large cells; valves rounded and slightly depressed in the centre. Rosette in centre or clear space, sometimes different in the same cell. Sculpture like *C. centralis*, but with granules scattered all over the valve surface. Spinulæ at margin, apicules further apart and flatter than in *C. centralis*. Diameter 150–300μ.

Distribution.—Bay of Biscay (stomachs of salps), Mediterranean.

This species is like *C. gigas*, *C. giganteus* and *C. prætextus* and their allies, but in these no trace of apicules has been found, nor granules on the valve surface.

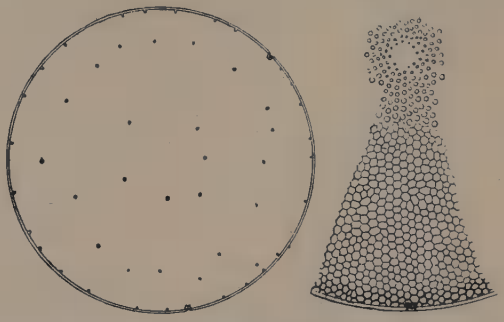


FIG. 22.—*Coscinodiscus Pavillardi* Forti, after Pavillard, 1925.

Group III. FASCICULATI.

Meshes or areoles in sectors, the sectors curved or straight. Spinulæ and one or two apicules present or absent. Valve usually more or less flat, girdle not known in all forms.

A. Rows of meshes or areoles in one sector running parallel to the ray of a sector.

Coscinodiscus curvatulus Grun. (Schmidt's Atlas, 1873–1904.)

(Fig. 23.)

Gran, Nordisches Plankton, pp. 35–36.

Valves flat with rather fine but distinct sculpture, the valve surface divided into sectors which are bounded by curved rays, the meshes or areoles running parallel to the lateral ray of each sector. No spinulæ, nor apicules in the typical forms. Diameter 45–100μ. Neritic.

Distribution.—Arctic Seas, North Atlantic, North Sea, Danish Seas, Finland, Mediterranean.

Specimens with straight rays and similar sculpture have been described, also specimens with spinulæ and apicules. There are probably several species described

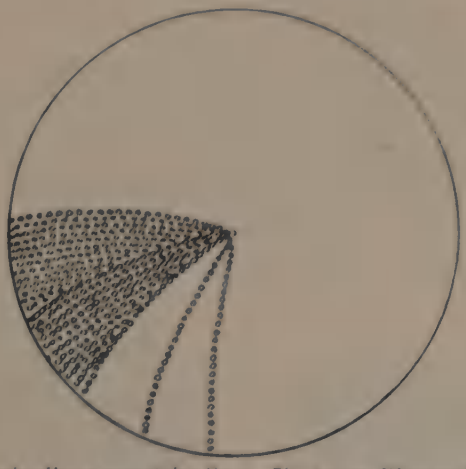


Fig. 23.—*Coscinodiscus curvatulus* Grun., 70μ across, Rhos'on Sea (M. V. L.).

under this name. Var. *karianus* Cleve and Grunow (Fig. 24), Ostenfeld, 1910, is like *C. curvatulus*, but with

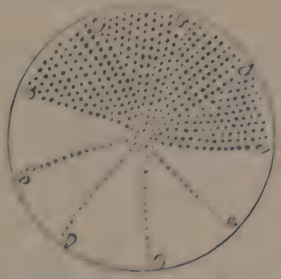


Fig. 24.—*Coscinodiscus curvatulus* var. *karianus* Cleve & Grun. After Cleve and Grunow, 1880.

a row of apicules and higher girdle with two intercalary bands. Ostenfeld thinks this is probably a distinct species.

Distribution.—Arctic Seas, Davis Strait in pack ice.

B. Rows of meshes or areoles in one sector running parallel to the middle radius.

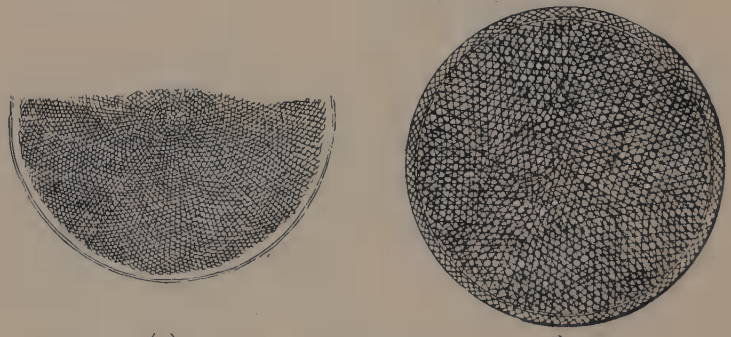
Coscinodiscus subtilis Ehr., 1841.

(Fig. 25*a*.)

Gran, Nordisches Plankton, p. 37.

Valves thin, with fine sculpture. Bundles of meshes run out from the centre, the parallel lines rather indistinct; oblique rays more distinct crossing the radial rays. Marginal spinulæ present. Diameter 40–120μ. Neritic.

Distribution.—Known from Greenland, Kamschatka, Franz Josef's Land, Norway, Antarctic; also from Vancouver.



(*a*) (*b*)

Fig. 25.—(*a*) *Coscinodiscus subtilis* Ehr., after A. Schmidt; (*b*) *Coscinodiscus Kutzingi* A. Sch. After A. Schmidt.

Probably several species are included here. Chiefly bottom forms, not truly planktonic. These include *C. Normanni* Greg.

Coscinodiscus Kutzingi A. Schmidt, 1873–1904.

(Fig. 25*b*.)

Gran, Nordisches Plankton, pp. 36–37.

Valves flat, with fine but distinct sculpture, dividing into sectors in which the radial rows of meshes run parallel with the middle radius of the sector. Other lines which run between form excentric curves, as in

C. excentricus, but more bent. No spinulæ or apicules. Girdle view unknown. Diameter 50–63μ. Neritic.

Distribution.—Polar seas, North Sea. A little-known species.

Coscinodiscus Joergensenii Ostenfeld, 1910.

Ostenfeld, 1910, p. 269 (= *C. polyacanthus* var. *intermedius* Grun. Jörgensen, 1905*a*).

(Fig. 26.)

Allied to *C. subtilis*, probably one of those species into which *C. subtilis* should be split. One row of small

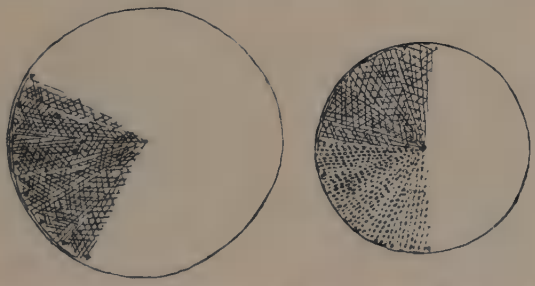


Fig. 26.—*Coscinodiscus Joergensenii* Ostenf. After Ostenfeld, 1910.

spinulæ. Fasciculæ like in *C. Kützingi* but with cross-bundles conspicuous. Sculpture fine. Diameter 50–80μ.

Distribution.—Probably Arctic-neritic, known from Cape Wankarema and Arctic Norway. Also pack ice in Greenland Sea (Ostenfeld).

Group IV. STELLARES.

Valve with a central star of nodules.

Coscinodiscus stellaris Roper, 1858.

(Pl. I, fig. 4.)

Gran, Nordisches Plankton, pp. 37–38.

Valves rounded. No spinulæ nor apicules. From the centre radiate three to six irregular star-like

thickenings. Sculpture very fine. No intercalary bands. Diameter 75–175μ. Oceanic.

Distribution.—Davis Strait, North Sea, Skaggerak, Irish Sea, Mediterranean, Antarctic.

Gran (' Nordisches Plankton ') also describes (p. 35) *Coscinodiscus marginatus* Ehr., 1841, from the North Atlantic, a heavy form with large meshes, possibly belonging to *C. centralis*, and (p. 38) *C. nididus* Greg., which is probably not a truly planktonic form. Only the valve face is known, which has no meshes, but round puncta scattered irregularly on the surface.

Other species recorded: *C. lacustris* Grun., freshwater, *C. augusto-lineatus* A. Sch. (probably a form of *C. excentricus* or *C. lineatus*). The following recorded by the International Fisheries Investigations are synonymous with others belonging to different genera: *C. decipiens* (= *Thalassiosira decipiens*), *C. polyacanthus* (= *Thalassiosira baltica*), *C. balticus* (= *Thalassiosira baltica*), *C. polychorda* (= *Coscinoscira polychorda*). The freshwater *Stephanodiscus astræa* (Ehr.) is closely related to *Coscinodiscus*, and occasionally found in the plankton.

Genus **PLANKTONIELLA** Schütt, 1893*a*.

Cells single, disc-shaped, with a wing-like expansion all round, consisting of extra-cellular chambers strengthened by radial rays.

Species: *Planktoniella sol* (Wallich).

Planktoniella sol (Wallich), 1860.

(Pl. I, fig. 5.)

Gran, Nordisches Plankton, p. 44.

Valves flat, sculpture like *Coscinodiscus excentricus*. Diameter, without border, 62–150μ. Oceanic. Probably living near the bottom.

Distribution.—North Sea, North Atlantic, English Channel, Mediterranean, tropical and sub-tropical seas.

Genus **ACTINOPTYCHUS** Ehr., 1843.

Cells single, disc-shaped. Valve divided into sectors alternately raised and depressed. Smooth central field.

Species: *Actinoptychus undulatus* (Bail.), *A. splendens* (Ehr.).

Actinoptychus undulatus (Bail.), 1842.

(Fig. 27.)

Gran, Nordisches Plankton, pp. 42–43.

Cell-wall strong. Central smooth field hexagonal. Six sectors, distinct, areolated, strongly curved on the outside and on the inside, so that the valve surface is

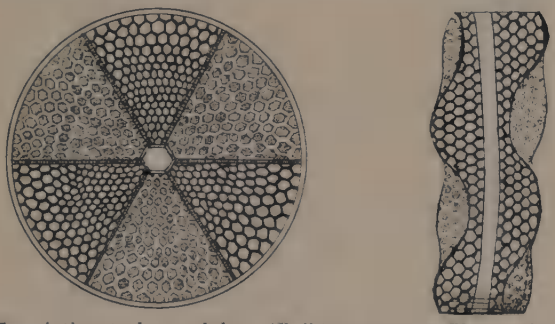


FIG. 27.—*Actinoptychus undulatus* (Bail.), 75μ across, Plymouth (G. E. W.).

twisted. Chromatophores numerous. Diameter 40–140μ. Neritic. Bottom form often appearing in the plankton. Likes a fairly high salinity. Auxospores observed by Meunier (1915) forming new cells.

Distribution.—All parts of the North Sea, Norwegian Seas, Danish Seas, Skaggerak, Baltic, North Atlantic, Finland, English Channel, West Coast of France, Mediterranean, Atlantic and Pacific American coasts.

Actinoptychus splendens (Ehr.), 1844.

(Pl. I, fig. 6.)

Gran, Nordisches Plankton, p. 43.

Central smooth field circular with conspicuous angles between the sectors. Sectors about 20, only slightly

rounded, often with fine reticulations. Diameter 70–180μ. Neritic.

Distribution.—Southern part of North Sea, Atlantic and Pacific American coasts.

Also recorded for this area, *Actinoptychus debya*, which should be *Debya* sp., belonging to a fossil genus.

Genus **ASTEROMPHALUS** Ehr., 1844.

Cells single, disc-shaped. Valves flat, areolated, smooth central field with only a few lines, from which run a number of smooth rays which are raised as soon as they leave the smooth field. A tendency to bilateral symmetry is shown by a ridge running outwards from the centre with broader ridges on each side. Chromatophores numerous, often arranged in rays.

Species : *Asteromphalus heptactis* (Bréb.), *A. Hookeri* Ehr.

Asteromphalus heptactis (Bréb.), 1857.

(Fig. 28*a*.)

Gran, Nordisches Plankton, pp. 44–45.

Usually seven rays of unequal length, the narrowest rather longer than the others. Central field not exactly in the middle of the cell, its diameter about one-third of the diameter of the cell. Meshes rather large (6 to about 10μ). Diameter 50–100μ (Gran). Oceanic. Temperate Atlantic form.

Distribution.—Atlantic Ocean, Davis Strait, Atlantic and Pacific America. Never in numbers.

Asteromphalus Hookeri Ehr., 1844.

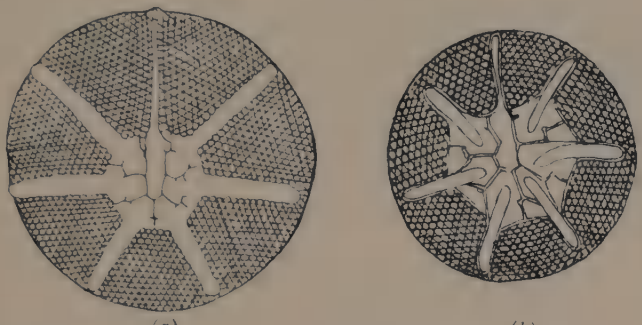
(Fig. 28*b*.)

Gran, Nordisches Plankton, p. 45.

Five to seven rays, almost of equal length. Central field in the middle of the valve, its diameter half as big as that of the valve. Meshes fine (10–12 to 10μ).

Diameter 25–50μ. Perhaps only a dwarf form of *A. heptactis*. (Gran). Oceanic. Northern temperate species.

Distribution.—North Atlantic, Greenland Sea. Also from the Antarctic, Pacific coast of America.



(*a*) (*b*)

FIG. 28.—(*a*) *Asteromphalus heptactis* (Bréb.); (*b*) *Asteromphalus Hookeri* Ehr. After Gran, 1905.

Genus **ACTINOCYCLUS** Ehr., 1839.

Cells single, like *Coscinodiscus*, but with a conspicuous "eye" or clear space in the valve margin. Valve sculpture radially arranged rows of puncta not crossing in a regular network. Marginal spinulæ often present. Chromatophores numerous.

Species: *Actinocyclus Ehrenbergi* Ralfs, *A. Ralfsii* (W. Sm.).

Actinocyclus Ehrenbergi Ralfs (in Pritchard, 1861).

(Pl. II, fig. 1.)

Gran, Nordisches Plankton, p. 40.

Valves thick-walled, strongly rounded at the margin, central portion flat. A large transparent marginal "eye" and a crown of far apart marginal spinulæ from which run rows of puncta towards the centre, which are surrounded by somewhat broader transparent parts. In the sectors between the radii the rows are parallel with the middle radius of the sector as in *Coscinodiscus*

subtilis. Marginal zone finely radially striated. No intercalary bands. Girdle bands smooth. Diameter 55–156μ. Neritic.

Distribution.—Cosmopolitan; known from all parts of the North Sea, Norwegian and Danish Seas, Gulf of Finland, Gulf of Bothnia, Baltic, Skaggerak, Aral and Caspian Seas, Black Sea, North Atlantic, Mediterranean, Atlantic and Pacific American coasts.

Ostenfeld (1908*a*) has shown that the cells in the plankton are surrounded by a viscous secretion which keeps them up.

Actinocyclus Ralfsii (W. Sm.), 1856.

(Pl. II, fig. 2.)

Gran, Nordisches Plankton, p. 39.

Valves thick-walled, strongly curved at the margins, with flat central part. Large transparent marginal "eye" and a crown of far-apart spinulæ. Rows of radial puncta arranged as in *A. Ehrenbergi*, in the middle part with rather wide intervals, farther out closer together, so that concentric zones are visible. Marginal zone with fine radial striations. Diameter 50–200μ. Neritic. Rarely in the plankton. Jörgensen (1905*a* and *b*) regards it as a truly planktonic form.

Distribution.—More southerly than *A. Ehrenbergi*; known from Western Europe, Norwegian Seas and Greenland, Pacific and Atlantic coasts of America.

Also recorded: *Actinocyclus subtilis* (Greg.), *A. crassus*, Van Heurck. Very rarely in the plankton.

Genus **EUPODISCUS** Ehr., 1839.

Like *Actinocyclus* in form. Near the margin with one to five "eyes" or small processes. No marginal spinulæ. The whole decorated with papillate knobs opening to the outside. No central space.

Species: *Eupodiscus argus* Ehr.

Eupodiscus argus Ehr., 1839.

(Pl. II, fig. 3.)

Gran, Nordisches Plankton, p. 41.

Valve thick-walled, strongly rounded, almost flat in the centre with 3–5 processes near the margin. Valve surface with polygonal chambers arranged in radial rows, opening to the outside, which communicate with the cavity of the cell by fine pores. The walls of the chambers and the membranous part between them (in the older forms) become covered with small granules. Girdle zone with many ring-like intercalary bands. Diameter 80–200μ. Neritic.

Distribution.—Coast of the North Sea and Western Europe, Baltic, English Channel, American North Atlantic coasts.

Also recorded : *Eupodiscus tesselatus* Roper, a littoral form of *E. zoodiacus*, is probably *Eucampia zoodiacus*.

Genus **EUODIA** Bail., Ralfs in Pritchard, 1861.

Cells single, shaped like a portion of an orange. Valves semicircular, with sculpture like *Coscinodiscus*. Chromatophores numerous, small.

Species : *Euodia cuneiformis* (Wallich).

Euodia cuneiformis (Wallich), 1860.

(Pl. II, fig. 4.)

Gran, Nordisches Plankton, pp. 45–46.

Valves semicircular to three-cornered, rounded, only slightly bent at the corners. Sculpture hexagonal, meshes in rows radiating from a centre, but not throughout radial as in *Coscinodiscus sub-bulliens*, the rows of meshes parallel with the limiting radius of a sector. Sculpture rather irregular at the margins. Marginal zone smooth. On the inner valve margin (straight or slightly curved in the middle) is a row of small spinulæ, and in the centre of it an " eye." No intercalary bands.

Cell low on the inner (straight) side, higher on the outer side. Diameter 73–100μ. Length of valve 120–220μ. Oceanic. Sub-tropical and southern tropical form, sometimes temperate and brought into our area.

Distribution.—Known from the North Sea, North Atlantic, Mediterranean, American coasts, both Atlantic and Pacific.

Family THALASSIOSIRACEÆ n. fam.

Cells disc-shaped or shortly cylindrical, united into chains by a thread or threads of cytoplasm, rarely without threads and embedded in a gelatinous cytoplasmic mass. Spinulæ usually present. Apicules present or absent.

Genus **THALASSIOSIRA** Cleve, 1873*a*.

Cells like *Coscinodiscus*, short, usually disc-shaped, united in flexible chains by a cytoplasmic thread with distinct gaps in between the cells, or rarely embedded in cytoplasm. Valves finely sculptured with a central axis and marginal spinulæ sometimes produced into distinct spines for the emission of slime-threads, which radiate outwards and may be much longer than the cell itself. Valves rounded or flat, not usually depressed in the centre. One or more intercalary bands to each valve, rarely several. Numerous small chromatophores. A truly planktonic genus, chiefly neritic and characteristic of the arctic neritic area which Cleve termed "sira" plankton, after the genus, in his classification of the various kinds of plankton. Specially adapted for floating, mainly inhabiting cold and temperate seas. Mostly with maxima in early spring, sometimes a second in autumn. Auxospores formed as large bladders by the separation of the valves and larger cells formed in these, known in *T. gravida* and *T. baltica*. Resting spores known in several species like biconvex lenses formed in the ordinary cells.

Species: *Thalassiosira Nordenskiöldii* Cleve, *T. decipiens* (Grun.), *T. gravida* Cleve, *T. rotula* Meunier,

T. fallax Meunier, *T. hyalina* (Grun.), *T. baltica* (Grun.), *T. bioculata* (Grun.), *T. condensata* (Cleve), *T. subtilis* (Ostenf.).

Thalassiosira Nordenskiöldii Cleve, 1873*a*.

(Fig. 29.)

Gran, Nordisches Plankton, pp. 16, 17.

Cells short, united into close, long chains by a fine thread. Girdle view somewhat octagonal. Small

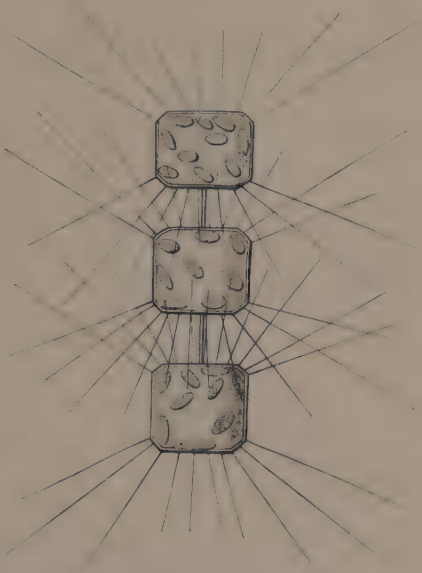


Fig. 29.—*Thalassiosira Nordenskiöldii* Cleve, 40μ across, Plymouth (G. E. W.).

spinulæ on the margin directed obliquely outwards. Sculpture very fine. Diameter 12–43μ. Neritic. Resting spores described by Meunier (1910). Maximum in early spring. Boreal Arctic species.

Distribution.—Arctic and boreal Atlantic, Davis Strait, rarely in Pacific, Arctic seas, Kara Sea, all parts of the North Sea, Gulf of Finland, Gulf of Bothnia,

Skaggerak, Kattegat, Irish Sea, English Channel, as far south as Central Europe, American Northern Atlantic.

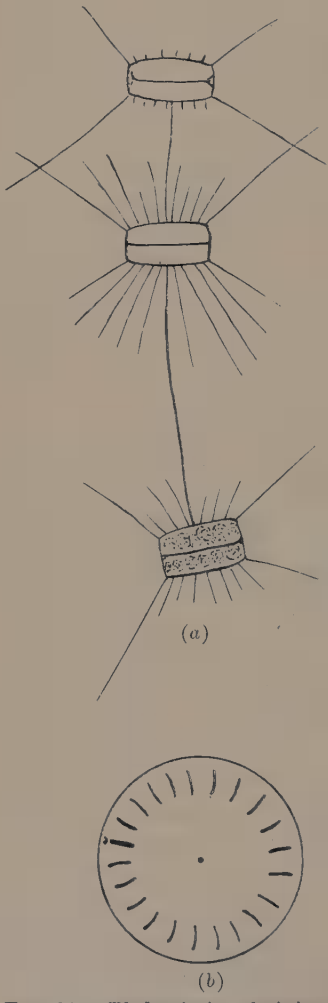


FIG. 30.—*Thalassiosira decipiens* (Grun.) (*a*) From culture by Dr. Allen, Plymouth (M. V. L.), 20μ across; (*b*) valve view showing marginal spines, North Atlantic "Scotia" material (M. V. L.).

Thalassiosira decipiens (Grun). in Van Heurck, 1880–85. (Fig. 30.)

Gran, Nordisches Plankton, p. 17.

Disc-shaped cells, united in loose chains with very long spaces between the cells. Valves slightly curved with margins rounded and a row of strong curved marginal spinulæ produced into spines and one apicule. Sculpture of valve like that of *Coscinodiscus excentricus* with meshes arranged in curved lines, not radiating from the centre. Diameter 12–40μ. Neritic. Inhabits coastal regions, often near the bottom. Maximum in early spring. North temperate species.

Distribution.—Sparingly in Davis Strait, not usually occurring south of the southern part of the North Sea and Mediterranean. Known from all parts of the North Sea, North Atlantic, Danish seas, Skaggerak, Cattegat, Baltic, Great and Little Belt, Kara Sea, Finland, English Channel, American side of the Atlantic. According to

Pavillard (1925) this is the only species which inhabits the Mediterranean. When occurring singly the cells are said to be difficult to distinguish from *Coscinodiscus excentricus*, although the rounded valves and the curved spines should enable it to be recognized.

Thalassiosira gravida Cleve, 1896*a*.

(Figs. 31; Pl. II, fig. 5*a*.)

Gran, Nordisches Plankton, p. 18.

Disc-shaped cells united in close chains by a thick thread. Girdle view oblong with rounded edges.

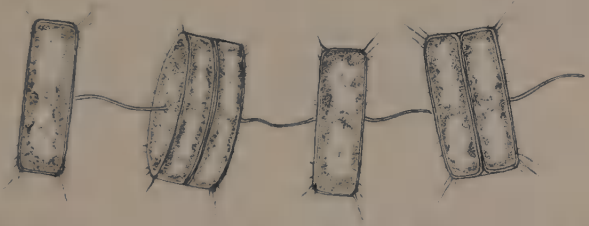


Fig. 31.—*Thalassiosira gravida* Cleve, 20μ across, Plymouth (G. E. W.).

Valve flat, with one small spine-like apicule and irregular rows of spinulæ. Valve sculpture radial but faint. Diameter 17–62μ. Neritic. Auxospores frequent. Resting spores smooth, described by Meunier (1910) as common in the Kara Sea. Maximum in early spring.

Distribution.—Northern form, not quite so Arctic as *T. Nordenskiöldii*. Davis Strait, common in all parts of the North Sea, Arctic Seas, Barents and Kara Seas, Norwegian and Danish seas, Skaggerak, Baltic, Great and Little Belts, Finland, North Atlantic, both European and American, Irish Sea and English Channel. As far south as Central Europe. Recorded from California.

May have been confused with *T. rotula*, a more temperate species. The specimens recorded by Mangin (1908) from the Brittany coast, which afforded the

material for the beautiful experiments on its minute structure, are regarded by Pavillard (1925) as belonging to *T. rotula*.

T. gravida is the commonest species of the genus at Plymouth, and well known from its being the subject of the very successful and important cultural experiments made by Dr. E. J. Allen and the late Mr. E. W. Nelson at the Plymouth Laboratory (1910).

Thalassiosira rotula Meunier, 1910.

(Pl. II, fig. 5*b*.)

Meunier, 1910, p. 264.

Cells disc-shaped, separated at regular distances by a very thick thread, thicker and more rigid than in any other species. Valves flat, only a little rounded at the extreme margin and relieved on the cylindrical girdle face by one or two thick rings, which are like narrow bandages applied to a very broad rim of a wheel. Nucleus central in a cord of cytoplasm. Many chromatophores round the edge and along the surface of the valve. Sculpture of valve small regular puncta arranged in no special order (Meunier). The valves look much like those of *Lauderia glacialis*. The thread has been analysed by Mangin (1908) by special methods and separated into several strands (as *T. gravida*). Diameter *ca.* 35μ. Neritic.

Distribution.—Common on the French and Flemish coasts. Probably a temperate species, not boreal.

Thalassiosira fallax Meunier, 1910.

(Pl. II, fig. 5*c*.)

Meunier, 1910, p. 268.

Cells like *T. gravida*, but smaller, and the resting spores having conspicuous small spines. Otherwise like *T. gravida*. Diameter *ca.* 15μ (Meunier). Neritic.

Distribution.—Nova Zembla.

Thalassiosira hyalina (Grun.) in Cleve and Grun., 1880.

(Fig. 32.)

Gran, Nordisches Plankton, p. 17.

Disc-shaped cells, united in close or loose chains. Valves flat, somewhat rounded at the edges, with one spine-like apicule and a single row of inconspicuous spinulæ. Valve sculpture very fine, radial. Diameter 16–50μ. Neritic.

Distribution.—Boreal-Arctic form. North Atlantic, both European and American, Norwegian seas.

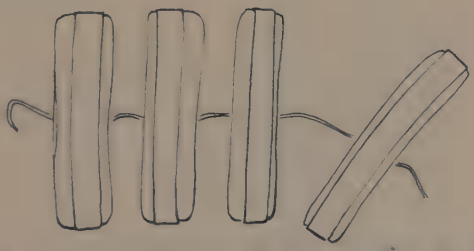


Fig. 32.—*Thalassiosira hyalina* (Grun.), 50μ across (G. E. W.).

Thalassiosira baltica (Grun.) in Cleve and Grun. 1880.

(Fig. 33.)

Gran, Nordisches Plankton, p. 18.

Disc-shaped cells, united by a thin thread into loose chains. Girdle view oblong, with rounded edges. Valves flat, with a few spines and several irregular rows of spicules (spinulæ ?). Valve sculpture rather like *Coscinodiscus curvatulus*. Auxospores described by Ostenfeld (1913*a*). Diameter 60–120μ. Neritic. Low salinity and brackish form.

Distribution.—Southern part of North Sea, Danish seas, Cattegat, Great and Little Belts, Gulf of Finland, Gulf of Bothnia, common in the Baltic. Also recorded from Gulf of Maine and California.

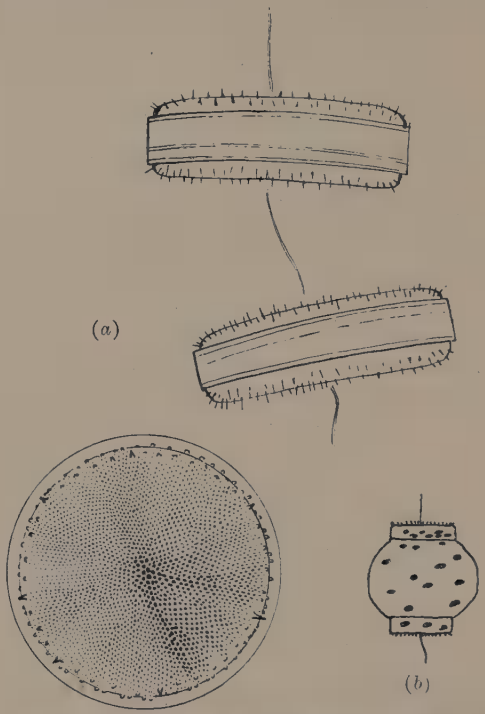


FIG. 33.—*Thalassiosira baltica* (Grun.). (*a*) 75μ across (G. E. W.); (*b*) forming auxospore, after Ostenfeld, 1913*a*.

Thalassiosira bioculata (Grun.), 1884.

(Fig. 34.)

Gran, Nordisches Plankton, p. 19.

Cells usually nearly as long as broad, or longer, with numerous intercalary bands, united into loose chains or living singly. Valves flat, with a single row of marginal spinulæ. Sculpture radial with two distinct transparent centres (slime-pores ?). Diameter 30–60μ. Neritic. Resting spores described by Meunier (1910) from the Kara Sea.

FIG. 34.—*Thalassiosira bioculata* (Grun.), forming resting spore. After Meunier, 1910.

Distribution.—Southern part of North Sea, North Atlantic, Flemish seas, Faroe Channel, Kara Sea, E. Greenland Sea.

Thalassiosira condensata (Cleve), 1900*a*.

(Fig. 35.)

Gran, Nordisches Plankton, p. 20.

Large oblong cells united in thick chains by a stout central thread. Valve depressed in centre, with a

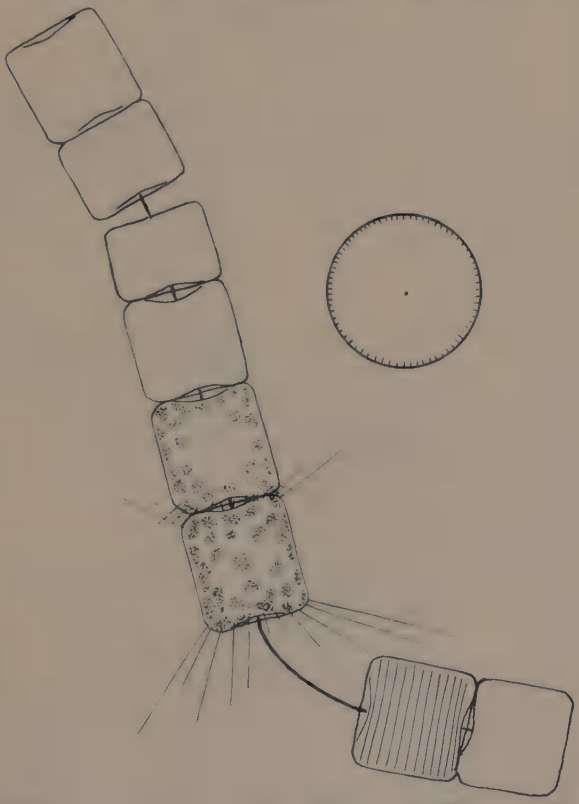


Fig. 35.—*Thalassiosira condensata* (Cleve), 17μ across, Plymouth (M. V. L.).

central pore and one row of marginal spinulæ. Numerous intercalary bands. Otherwise looks very like *Lauderia borealis*. Diameter 17–30μ. Neritic.

Distribution.—English Channel, California ?

The writer is indebted to Professor Gran for the identification of this species, which she has often mistaken for *Lauderia*. It was originally described by Cleve (1900*a*) from Plymouth, but never since identified here until Professor Gran re-discovered it. Also obtained in cultures by Dr. Allen. Fairly common at Plymouth.

Thalassiosira subtilis (Ostenfeld), 1899.

(Fig. 36.)

Gran, Nordisches Plankton, p. 19.

Small box-like cells in colonies embedded in a gelatinous mass. Valves rounded, without distinct sculpture,

FIG. 36.—*Thalassiosira subtilis* (Ostenfeld), 15μ across, Plymouth (G. E. W.).

with one small apicule. Diameter 15–32μ. Oceanic. Temperate Atlantic form.

Distribution.—Northern part of North Sea, North Atlantic, English Channel (common at Plymouth), California.

Genus **COSCINOSCIRA** Gran, 1900*b*.

Cells like *Thalassiosira*, but united by several threads coming from corresponding pores.

Species : *Coscinoscira polychorda* (Gran.), *C. Oestrupi* Ostenf.

Coscinoscira polychorda (Gran), 1897*a*.

(Fig. 37.)

Gran, Nordisches Plankton, p. 20.

Valves flat, with distinct reticulate sculpture and one row of spinulæ. Four to nine slime-pores near the centre of the circle. Diameter 24–76μ. Neritic. Maximum in early spring.

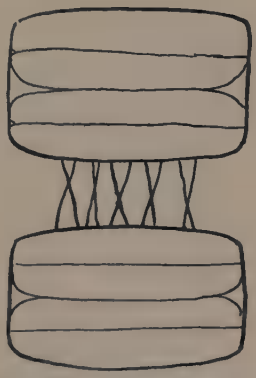


Fig. 37.—*Coscinoscira polychorda* (Gran), 24μ across, Plymouth (M. V. L.).

Distribution.—Arctic seas, Davis Strait, Barents and Kara Seas, all parts of North Sea, Danish seas, Skaggerak, North Atlantic, English Channel, Mediterranean, Gulf of Maine.

Coscinoscira Oestrupi Ostenfeld, 1900.

(Pl. III, fig. 1.)

Gran, Nordisches Plankton, p. 21.

Valves flat or slightly rounded, with distinct rather irregular reticulations, which are coarser in the centre than round the margins. No marginal spinulæ. Numerous mucus threads. Diameter 10–24μ. Oceanic. Karsten (1907) figures it from the Indian Ocean.

Distribution.—North Atlantic, North Sea, Indian Ocean.

Genus **LAUDERIA** Cleve, 1897*a*.

Cells shortly cylindrical, united in straight chains by very fine slimy threads, the cells either touching or separated. Valve with an unpaired oblique outwardly-directed apicule, and numerous very small spinulæ (slime-canals) at the margin and over the valve surface. Centre of valve slightly sunk in. Intercalary bands numerous, collar-shaped, more or less conspicuous. Chromatophores numerous small plates. Cell nucleus suspended in a cord of cytoplasm, which binds the central parts of the valves together and also helps to form the chains.

Species : *Lauderia borealis* Gran, *L. glacialis* (Grun.).

Lauderia borealis Gran, 1900*b*.

(Fig. 38.)

Gran, Nordisches Plankton, p. 23.

Cells close together in thick straight chains, touching by their valve surfaces. Valve slightly indented in the

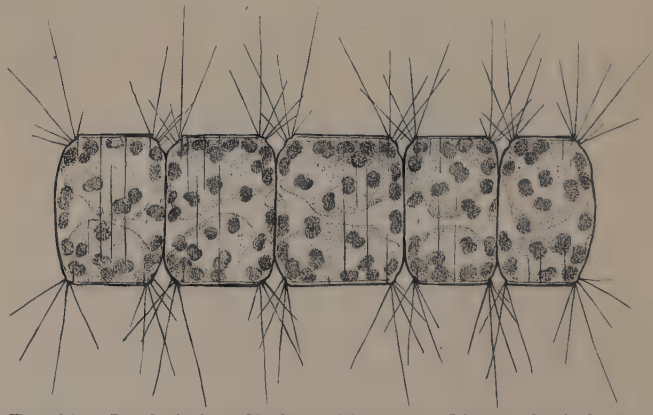


Fig. 38.—*Lauderia borealis* Gran, 38μ across, Plymouth (G. E. W.).

centre, rounded at the margins. Marginal spinulæ straight with gelatinous straight radiating threads. Diameter 34–38μ. Neritic. No resting spores known.

Distribution.—Temperate species, very common in the North Atlantic, known from all parts of the North Sea, English Channel, Flemish coast, Mediterranean, California. More southern form than *L. glacialis*. According to Ostenfeld (1903) it follows the west coast of Europe from the English Channel and Baltic, northwards towards Norway.

Lauderia glacialis (Grun.), 1884.
(Fig. 39.)

Gran, Nordisches Plankton, pp. 23–24.

Cells short, in loose chains, bound together by several indistinct and very fine slimy threads. Valves rounded and armed with small spinulæ on the whole face. Resting spores in the parent cells lens-shaped and covered with small spicules. Diameter 36–64μ. Maximum in early spring. Neritic. Northern sub-Arctic species.

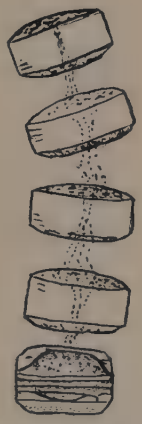


Fig. 39.—*Lauderia glacialis* (Grun.). After Gran (1900*b*).

Distribution.—Arctic Seas, Davis Strait, Kara and Barents Sea, North Sea, Danish seas, Skaggerak (absent from Baltic), North Atlantic, European and American, English Channel.

Genus **SCHRÖDERELLA** Pavillard, 1913.

Cells cylindrical, forming straight chains, sometimes occurring singly. Valve flat or slightly convex, but depressed in the centre, where there is a distinct spine, which joins its neighbour belonging to the next cell. Margin surrounded by a row of small spinulæ, from each of which issues two gelatinous threads, which diverge and join the corresponding thread, thus forming a characteristic zigzag; the threads are, however, or appear to be, sometimes straight. Many intercalary

bands forming incomplete hoops. Minute puncta on the bands. Auxospores and resting spores formed.

Species: *Schröderella delicatula* (Péragallo), *S. Schröderi* (Bergon).

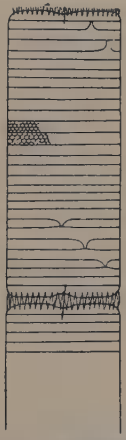


Fig. 40.—*Schröderella delicatula* (Péragallo). After Pavillard, 1913.

Schröderella delicatula (Péragallo), 1888.

(Fig. 40.)

Pavillard, 1913, p. 126; 1925, p. 22 (= *Lauderia delicatula* Péragallo, 1888; Cleve, 1897*b*; Schröder, 1900*a*; *Detonula Schröderi* Gran, Nordisches Plankton, p. 22).

Cells longer than broad (2–5 times), in cylindrical dense rigid chains. Valves almost flat, hardly convex, distinctly depressed in the centre for the insertion of the spine. Spaces between the cells very short. Diameter 22–28μ. Neritic.

Distribution.—Known from the Atlantic on the French coast, Mediterranean. It is difficult to know its exact distribution, as it has probably been much confused with *S. Schroderi*.

Schröderella Schröderi (Bergon), 1903*a*.

(Fig. 41.)

Pavillard, 1925, p. 23 (= *Lauderia Schröderi* Bergon, 1903*a*).

Cells oblong cylinders, forming loose chains with definite spaces between the cells. Valves convex with central depression for spine, which is conspicuous and well developed, and so also are the connective filaments. Length of cell about the same as the breadth, but

sometimes longer. Auxospores frequently seen. Bergon found resting spores. Diameter 13–40μ. Neritic.

Distribution.—Northern form, Atlantic French coast, Irish Sea, English Channel.

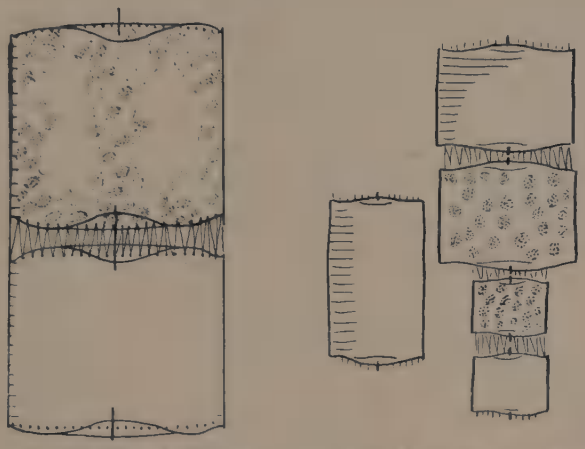


Fig. 41.—*Schröderella Schröderi* (Bergon), 13 to 26μ across, 14 miles beyond Plymouth Breakwater (M. V. L.).

Genus **BACTERIOSIRA** Gran, 1900*b*.

Cells cylindrical. United in thick chains. Valve surfaces touching except in the centre, where there is a depression. Valves with a single row of minute spinulæ. Each cell with one pair of collar-like intercalary bands. Cell-wall thin. Chromatophores numerous, small plates. Nucleus close to cell-wall. Resting spores known.

Species : *Bacteriosira fragilis* Gran.

Bacteriosira fragilis Gran, 1900*b*.

(Fig. 42.)

Gran, Nordisches Plankton, p. 21.

Chains thick, constricted slightly where the cells touch. Cells slightly longer than broad. Valves flat

Fig. 42.—*Bacteriosira fragilis* Gran, 16μ across. N. Atlantic, "Scotia" material (M. V. L.).

with small marginal spinulæ, slightly sunk in the centre, so that the neighbouring cells do not touch there. Intercalary bands bordering the girdle band as a ridge-like thickening. Resting spores like those of *Thalassiosira*, described by Meunier (1910). Diameter 16–20μ. Neritic.

Distribution.—Arctic form, Greenland seas, Davis Strait, North Norway, Faroe-Shetland Channel, north of Barents Sea, Gulf of Maine (?).

Family Skeletonemaceæ n. fam.

Cells united in chains by spines surrounding the margin.

Genus **SKELETONEMA** Greville, 1865.

Cells circular, lens-shaped, oblong or cylindrical. Without distinct sculpture, provided at the valve margin with a row of spines parallel to the longitudinal axis, which by interlocking unite the cells into chains and through which the cytoplasm is in contact with the adjoining cell. Chromatophores 1–2 in each cell. Auxospores formed, described by Schütt (1893) in *S. costatum*.

Species: *Skeletonema costatum* (Greville), *S. mirabile* Grunow.

Skeletonema costatum (Greville), 1866.

(Fig. 43.)

Gran, Nordisches Plankton, p. 15.

Chains long, thin, usually straight. Cells with rounded ends hanging together by long straight spines. Spaces between the cells usually longer than the cells themselves. Diameter 7–16μ. Neritic.

One of the commonest coastal diatoms and very variable in form (Karsten, 1898). The cells may be thick and short or long and thin, and although the chains are typically straight, they may be curved, or even spiral. Maximum in early spring, usually another in autumn. It is recorded from all areas investigated by the International Fisheries and occurs in all seas, usually close to the coast. It may, however, flourish

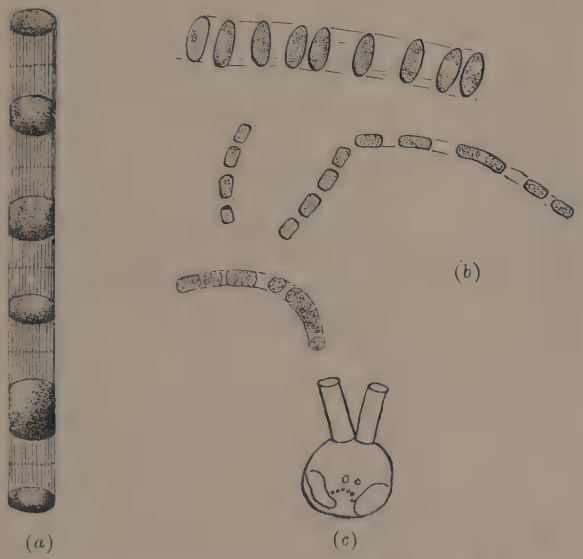


FIG. 43.—*Skeletonema costatum* (Greville). (*a*) 8μ across, Plymouth; (*b*) from culture by Dr. Allen showing different forms (G. E. W.); (*c*) auxospore, after Schütt, 1893.

in certain parts of the ocean, where, by the mixing of large currents, an area of still water is formed, such as the meeting-place of the Labrador current and the Florida Stream. It is not much affected by salinity, and may be abundant where the salinity is very low, as, for instance, in the Baltic (Lohmann, 1908), and many Scottish lochs (Marshall and Orr, 1927), but it can also flourish in water of a high salinity. It is a true member of the plankton, but at times lives far down

near the bottom. Unlike *Paralia* and *Hyalodiscus*, which are tychopelagic, it reproduces in the plankton and rests near the bottom, behaving like an ordinary neritic species. It is chiefly common in the plankton when the water is coldish. Lohmann (*op. cit.*) records 778,000,000 cells in 100 litres of water from Kiel. Very common in laboratory cultures at Plymouth.

Distribution.—Cosmopolitan, all seas, chiefly near the coast.

Fig. 44.—*Skeletonema mirabile* Grun. After Van Heurck, 1880–85.

Skeletonema mirabile Grun., in Van Heurck, 1880–1885.

(Fig. 44.)

Gran, Nordisches Plankton, p. 15.

Chains short, spines longer than the cells, in their outer part dichotomously branched, otherwise straight and unbranched. Diameter about 15μ.

Distribution.—Very rare. Only found twice at Cape Wankarema in Siberia and Bergen, Norway. Also recorded by Karsten (1907) in the Indian Ocean.

Genus **STEPHANOPYXIS** Ehr., 1844.

Cells oval, oblong or nearly circular, with hexagonal areolations. Margins rounded, with a crown of stout spines through which the cytoplasm is in contact from cell to cell. Usually in short chains. Girdle between two cells reaching from centre to centre, without intercalary bands. Chromatophores rounded, small and numerous. Resting spores described by Ostenfeld (1901*a*) and Lloyd (1925).

Species: *Stephanopyxis turris* (Greville,) *S. Palmeriana* (Grev.) Grunow.

Stephanopyxis turris (Greville), 1859.
(Figs. 45, 46.)

Gran, Nordisches Plankton, p. 14.

Cells circular, oblong or ellipsoidal, with 10–28 spines at each end, thickened slightly at the tips. Areolations coarse, about eight in a row from centre of cell to margin of valve in girdle view, all about the same size and not smaller at the valve margin. Girdle between two cells leaving a space between the halves of two alternate cells. Diameter 35–65μ. Resting spores formed in spring, described by Ostenfeld with thick walls and strong spines at two consecutive ends of neighbouring cells. Also figured by Lloyd. Neritic.

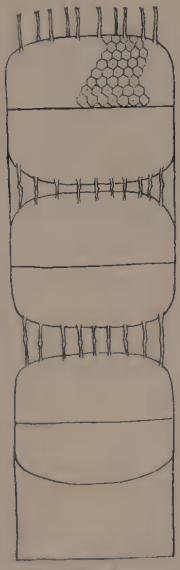


Fig. 45.—*Stephanopyxis turris* (Greville), 60μ across, Rhos-on-Sea (M. V. L.).

Distribution.—Temperate and subtropical seas. Atlantic, European coasts, known from Irish Sea, North Sea, Danish seas, Skaggerak, Cattegat. Probably enters Danish waters by the Jutland current. Not so far found in the English Channel. The Antarctic form figured by Karsten (1905) is probably a different species, with much smaller meshes, but not decreasing in size towards the margin

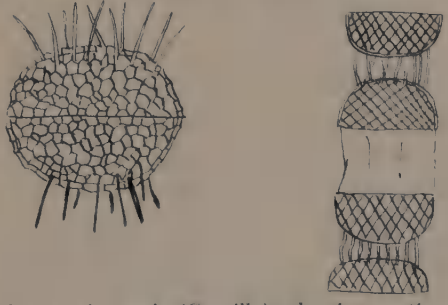


Fig. 46.—*Stephanopyxis turris* (Greville), showing resting spores. After Ostenfeld, 1901*a*.

as in *S. Palmeriana*. The American records of this species may not be *S. turris*.

Stephanopyxis Palmeriana (Grev.) Grunow, 1884.
(Fig. 47.)

Pavillard, 1925, p. 5.

Cells oblong, in shape very like *S. turris*, but with much finer areolations, dwindling in size towards the valve margin. Pavillard has distinguished between this species and *S. turris*, which may be very like it. His specimens are larger, 80μ in diameter, broader than long, in short chains. Neritic.

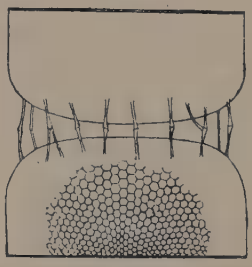


FIG. 47.—*Stephanopyxis Palmeriana* (Grev.) Grun. After Pavillard, 1925.

Distribution.—Atlantic, W. African coast, Indian Ocean, Mediterranean. Rarely in our area. As Pavillard remarks, the distribution of these two species, apparently so easily confused, will have to be revised, but it is certain that both may occur in the Atlantic. *S. turris* is probably a colder water form than *S. Palmeriana*.

Genus **DETONULA** Schütt, 1893*b*.

Cells cylindrical or oblong, united usually in straight chains, sometimes curved. Valves circular, with a single row of marginal spines, with no unpaired apicule. Several intercalary bands. Chromatophores numerous. Nucleus attached to the margin of the cell. Resting spores known.

Species : *Detonula cystifera* Gran.

Detonula cystifera Gran, 1900*b*.

(= *Detonula confervacea* Cleve, 1896*b*.)

(Figs. 48, 49.)

Gran, Nordisches Plankton, p. 21–22.

Cells one and a half to three times longer than broad, united in thick chains, which are hardly constricted at

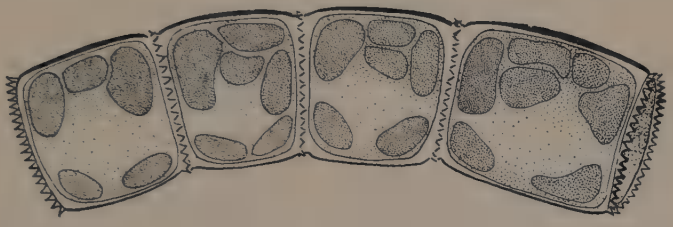


FIG. 48.—*Detonula cystifera* Gran, 5μ across. From culture by Dr. Allen, Plymouth (G. E. W.).

the junction of the cells. Valves flat, beset at the margin with a crown of short spines. Intercalary bands numerous, but hardly perceptible. Resting spores described by Gran, 1900*b*. Diameter 5–15μ. Neritic.

FIG. 49.—*Detonula cystifera*, resting spores. After Gran, 1900*b*.

Distribution.—Davis Strait, Limfjord in Denmark, South Norwegian seas, Gulf of Maine. Probably widely distributed. In culture by Dr. Allen at Plymouth.

Family LEPTOCYLINDRACEÆ n. fam.

Cells cylindrical, living singly or united in chains by the flat valve faces. Many collar-like intercalary bands.

Genus **DACTYLIOSOLEN** Castracane, 1886.

Cells cylindrical, living singly or united in chains by the flat valve-faces. Numerous intercalary bands,

which are slightly spiral, with overlapping and pointed ends.

Species : *Dactyliosolen antarcticus* Castr., *D. mediterraneus* Péragallo.

Dactyliosolen antarcticus Castr., 1886.

(Fig. 50.)

Gran, Nordisches Plankton, p. 25.

Cells single or in chains, twice or more longer than broad. Intercalary bands distinct, each with a row of large and somewhat oval puncta. The free ends of the intercalary bands form a spiral line round the axis. Diameter 38–68μ. Oceanic. Temperate Atlantic form.

Distribution.—Northern part of North Sea and North Atlantic (European and American), Arctic and Antarctic, California.

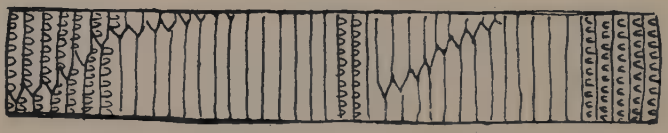


Fig. 50.—*Dactyliosolen antarcticus* Castr. After Cleve, 1900*a*.

Dactyliosolen mediterraneus Péragallo, 1892.

(Fig. 51.)

Péragallo 1892, Pavillard 1925 (= *D. tenuis* (Cleve); Gran, Nordisches Plankton, p. 25).

Cells longer and narrower than in *D. antarcticus*, with reticulated sculpture, both on the valves and intercalary bands. Nearly always found with a yellow epiphytic flagellate *Solenicola setigera* on the chains (see above, p. 18). Pavillard (1916*b*, 1925) has shown that *D. tenuis* Cleve is a thin form of *D. mediterraneus*, which was found by Cleve himself (1901*a*) in the Mediterranean. Diameter 10–30μ. Neritic ? Atlantic form.

Distribution.—North Atlantic, North Sea, Mediterranean. Very rarely in Antarctic. Recorded from California.

Fig. 51.—*Dactyliosolen mediterraneus* Péragallo. After H. and M. Péragallo, 1892.

Genus **LEPTOCYLINDRUS** Cleve, 1889.

Cells long and cylindrical, united by the whole valve surface. Valves flat, unarmed. Chromatophores two or several. Intercalary bands very difficult to see, not spiral. Resting-spores formed in auxospores by the separation of the valves.

Species: *Leptocylindrus danicus* Cleve, *L. minimus* Gran.

Leptocylindrus danicus Cleve, 1889.

(Fig. 52*a*, *b*, *d*.)

Gran, Nordisches Plankton, p. 24.

Cells two to five times longer than broad, neighbouring cells often with only one cell-wall between two valves. Chromatophores numerous. Diameter 6–11μ. Resting spores covered with spicules, first described by Gran, 1915, later found in cultures by Dr. Allen at Plymouth. Probably a temperate species. Neritic? Likes a high salinity usually, but is abundant in Scottish lochs. Gran (1928) recently found it in large numbers in Davis Strait. Behaves like *Skeletonema*. North temperate species.

Distribution.—Arctic seas, Davis Strait, Barents and Kara Seas, Norwegian seas, Danish seas, all parts of the North Sea, North Atlantic, English Channel, Mediterranean, Atlantic and Pacific America. Isolated specimens in Antarctic.

Leptocylindrus minimus Gran, 1915.

(Fig. 52*c*.)

Gran, 1915, p. 72 (= *L.* sp. Lebour, 1917; *L. belgicus* Meunier, 1913).

Smaller than *L. danicus*, with only two chromatophores. Chains straight or curved. Diameter *ca.* 5μ. Neritic.

Distribution.—Davis Strait, Kiel, Flemish coast, English Channel.

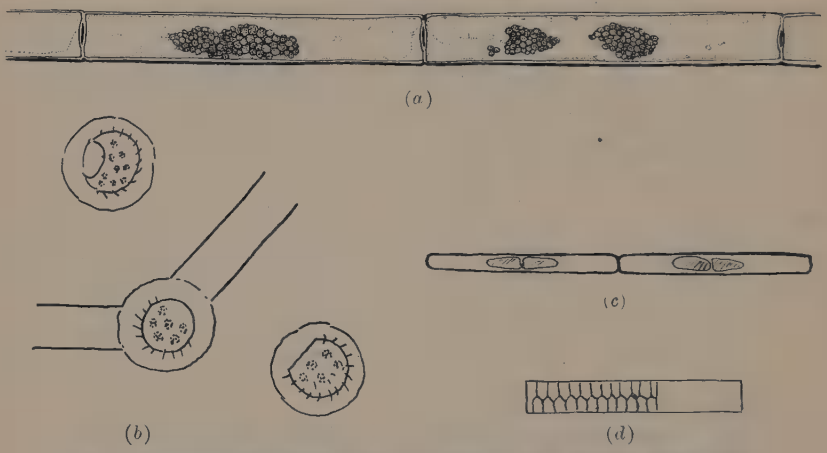


Fig. 52.—(*a*) *Leptocylindrus danicus* Cleve, 10μ across, Plymouth (G. E. W.); (*b*) *Leptocylindrus danicus* with resting spores, 15μ across, from culture by Dr. Allen, Plymouth, September 30th, 1927 (M. V. L.); (*c*) *Leptocylindrus minimus* Gran, 5μ across, Plymouth (M. V. L.); (*d*) *Leptocylindrus danicus* showing intercalary bands. After Mangin, 1908.

Genus **GUINARDIA** H. Péragallo, 1892.

Cells cylindrical, longer than broad, living singly or united in chains by the whole valve surface, which is flat. An asymmetrical lateral tooth at the valve margin. Numerous collar-like intercalary bands. Many chromatophores. Nucleus suspended by cytoplasmic strands.

Species: *Guinardia flaccida* Castr.

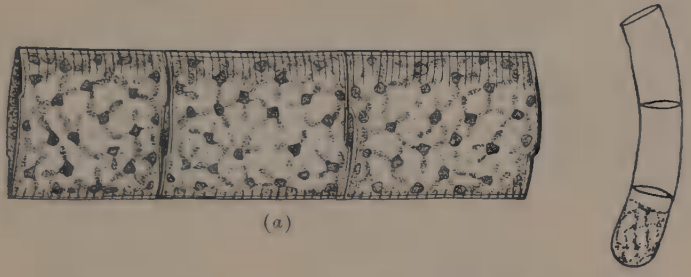
This genus is usually placed in the *Solenoneæ*. It has been removed because it seems to the writer that it is more closely related to those forms which are united by their flat valve surfaces, but it probably leads up to *Rhizosolenia*.

Guinardia flaccida Castr. 1886.

(Fig. 53.)

Gran, Nordisches Plankton, pp. 24–25.

Cells single or in chains, one and a half to two and a half times longer than broad. Valve almost flat, very



(*a*) (*b*)

FIG. 53.—*Guinardia flaccida* Castr. (*a*) 53μ across, Plymouth (G. E. W.); (*b*) showing auxospore. After Pavillard, 1916*b*.

slightly concave, with an irregular tooth at the margin. Diameter 42–90μ. Neritic. South temperate species. Auxospores formed from the ordinary cells, rounded, described by Gough (1907), Ostenfeld (1913*a*), Pavillard (1916).

Distribution.—All parts of the North Sea, Baltic, Danish seas, Skaggerak, North Atlantic, European and American, English Channel, Mediterranean.

Family CORETHRONACEÆ n. fam.

Cells cylindrical with rounded valves, solitary. Valves with long spines radiating outwards at an angle from the margin. Scale-like intercalary bands, very inconspicuous. *Corethron* is usually placed in the

SOLENOIDÆ, but here again although probably closely related to *Rhizosolenia* and very difficult to place it seems more close to the DISCOIDÆ as here emended.

Genus **CORETHRON** Castracane, 1886.

Cells living singly, cylindrical with rounded valves, which bear at the margin a crown of long thin spines directed outwards at an angle. Numerous intercalary bands, scale-like and very indistinct.

Species : *Corethron criophilum* Castr.

Corethron criophilum Castr., 1886.

(Fig. 54.)

Gran, Nordisches Plankton, p. 57.

Thin cell-wall, numerous chromatophores, small and long. Diameter 20–90μ. Spines long, those of the two

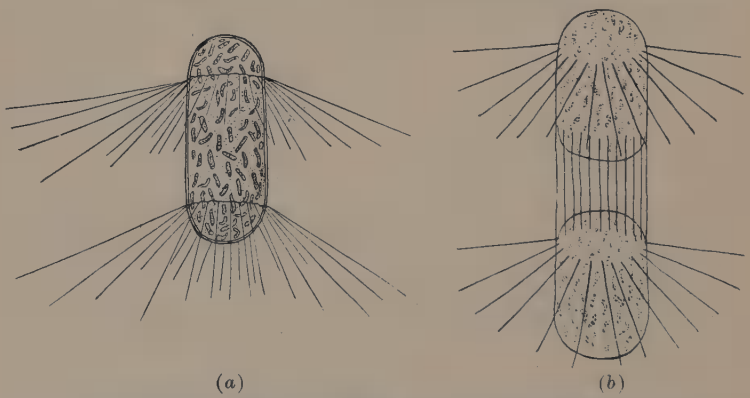


FIG. 54.—*Corethron criophilum* Castr. (*a*) In usual vegetative condition, 35μ across, Plymouth (G. E. W.); (*b*) dividing, Plymouth (M. V. L.).

valves directed in the same way. When dividing the spines of the new valve lie straight within the girdle bands. Karsten (1904) has described spore-formation in the Antarctic species *Corethron valdiviæ*. Oceanic. Temperate species.

Distribution.—Arctic seas, Davis Strait, Northern part of the North Sea, Skaggerak, North Atlantic (its headquarters), English Channel, Mediterranean, Atlantic and Pacific America.

Family Bacteriastraceæ n. fam.

Cylindrical cells united in chains by the fusion of long bristles sticking out at regular intervals from the circular valve face. Short spaces between the cells.

Bacteriastrum is usually placed in the Biddulphioidæ, close to *Chætoceros*, and is now transferred because of its circular section and the circlet of bristles, which seem to the writer to be more closely related to the Discoidæ, as emended. It is, however, undoubtedly nearly related to *Chætoceros*, but difficult to place, its resting spores being very like those of *Chætoceros*, but the regular circlet of bristles differing entirely from the two poles of that genus.

Genus **BACTERIASTRUM** Shadbolt, 1854.

Cells cylindrical. Valves with several regularly-arranged marginal bristles, by the fusion of which the cells are united in chains. The bristles of two neighbouring cells are fused for a certain length outside the base, further out separating again. End bristles different from the others, often curved, not fusing with other bristles, in valve view, therefore, not bifurcating. Chromatophores several in each cell. Resting spores near the middle of the cell with small spines on one valve.

Species : *Bacteriastrum delicatulum* Cleve, *B. hyalinum* Lauder, *B. elongatum* Cleve, *B. solitarium* Mangin.

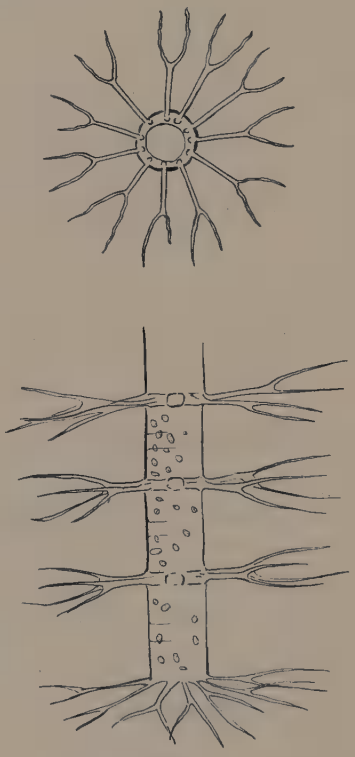
The genus *Bacteriastrum* has recently been revised by Pavillard (1924*b*, 1925), who shows that *B. varians* Lauder is a tropical species, which does not occur in our area, and that most of the species recorded for Northern seas as *B. varians* belong to *B. delicatulum*, *B. hyalinum* and possibly *B. elegans*.

A. With terminal bristles the same at both ends.

Bacteriastrum delicatulum Cleve, 1897*a*.

(Fig. 55.)

(= *Bacteriastrum varians* Lauder, var. *borealis* Ostenfeld, 1901*a*, and *B. delicatulum* Cleve.) Gran, Nordisches Plankton, pp. 57–58.)



(*a*)

Fig. 55.

Cells a little longer than thick, 12–40μ in diameter. Bristles about 6 to 11, perpendicular to the chain axis; basal part long, with bifurcations far from the cell in a plane at right angles to the cell axis. End bristles spirally curved (corresponding to *C. curvatulum* of Shadbolt, the inside cells corresponding to his *B.*

furcatum). The end bristles are bent over like an open umbrella. Resting spores seen and described by Ostenfeld (1899), formed in the centres of the cells; biconvex lens, with spines on one valve (the primary valve), which is much rounded, the other less so, and smooth. Oceanic. Temperate form.

Distribution.—North Atlantic, Europe and America, Faröe-Shetland Channel, Mediterranean. Probably often recorded as *B. varians*.

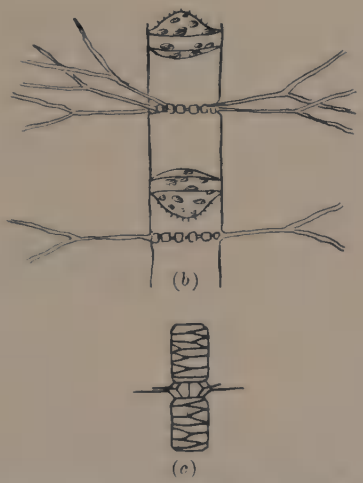


Fig. 55.—(*a*) *Bacteriastrum delicatulum* Cleve, 10μ across (G. E. W.); (*b*) with resting spores, after Ostenfeld, 1901*a*; (*c*) showing intercalary bands. After Mangin, 1908.

Bacteriastrum hyalinum Lauder, 1864.

(Fig. 56.)

(= *B. varians* Lauder, Meunier, 1915.)
Pavillard, 1925, p. 37.

Cells not much longer than broad. Diameter 20–30μ in temperate seas, up to 55μ in warmer seas. Number of bristles from 16 to 32. Terminal bristles differ a little from those of *B. delicatulum*, but those of the internal cells have the bifurcations parallel to the

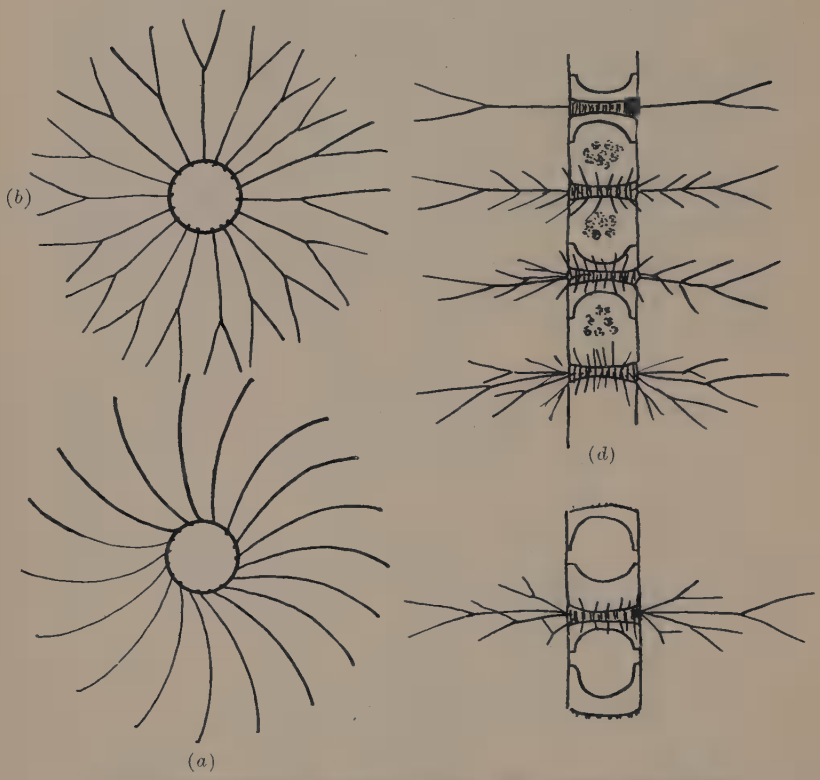


FIG. 56.—*Bacteriastrum hyalinum* Lauder, 25μ across, Rhos-on-Sea (M. V. L.); (*a*) top, valve view; (*b*) middle, valve view; (*c*) cell with chromatophores; (*d*, *e*) showing resting spores.

chain axis instead of transverse, thus giving the cells a hairy appearance. Resting spores like those of *B. delicatulum* (when in the process of formation, however, they are smooth, and only have the spicules in the fully-formed spores.) Microspores formed, described by Meunier. Many resting spores formed in specimens from the coast of Wales, where this species is very abundant. Neritic.

FIG. 56.

Distribution.—Known from the coast of Wales, Belgian coast, Mediterranean. Probably also recorded as *B. varians*.

Bacteriastrum elongatum Cleve, 1897*b*.

(Pl. III, fig. 2*a*.)

Gran, Nordisches Plankton, p. 58.

Cells several times longer than broad, diameter 7–10μ. Cell-wall very thick. Bristles 5–7, basal part short, outer part bifurcating, with the branches in a plane parallel to the chain axis. End bristles very thick, sticking out obliquely from the cell in a cup-like form. Oceanic.

Distribution.—More southerly species than *B. delicatulum* and *B. hyalinum*. North Atlantic, rare, Mediterranean, tropical seas.

Bacteriastrum solitarium Mangin, 1912.

(Pl. III, fig. 2*b*).

Mangin, 1912, p. 37.

Cells solitary, disc-shaped, valves plano-convex, diameter 38–48μ, with a single or double crown of 30–42 simple spines, radial and curving outwards. Spores in the cells convex, with rounded valves, smooth, the cylindrical part equal to or more than a fifth part of the length (Mangin).

Distribution.—North of the Loire.

Bacteriastrum elegans Pav. may belong to our area, as Pavillard (1925) thinks it is to this species that many of the specimens recorded in our area should be referred. This species belongs to the section where the bristles are arranged differently on the two terminal cells.

Group B. SOLENOIDÆ Schütt, 1896.

Cells rod-like or cylindrical with an excentric apex or a spine at the side. Intercalary bands in the form of overlapping scales.

Family RHIZOSOLENIACEÆ Schröder, 1911.

With the characters of the group.

Genus **RHIZOSOLENIA** (Ehr.), Brightwell, 1858*a*.
(Fig. 57.)

Cells cylindrical, straight, or more rarely curved, living singly or in chains. Valve with an excentric

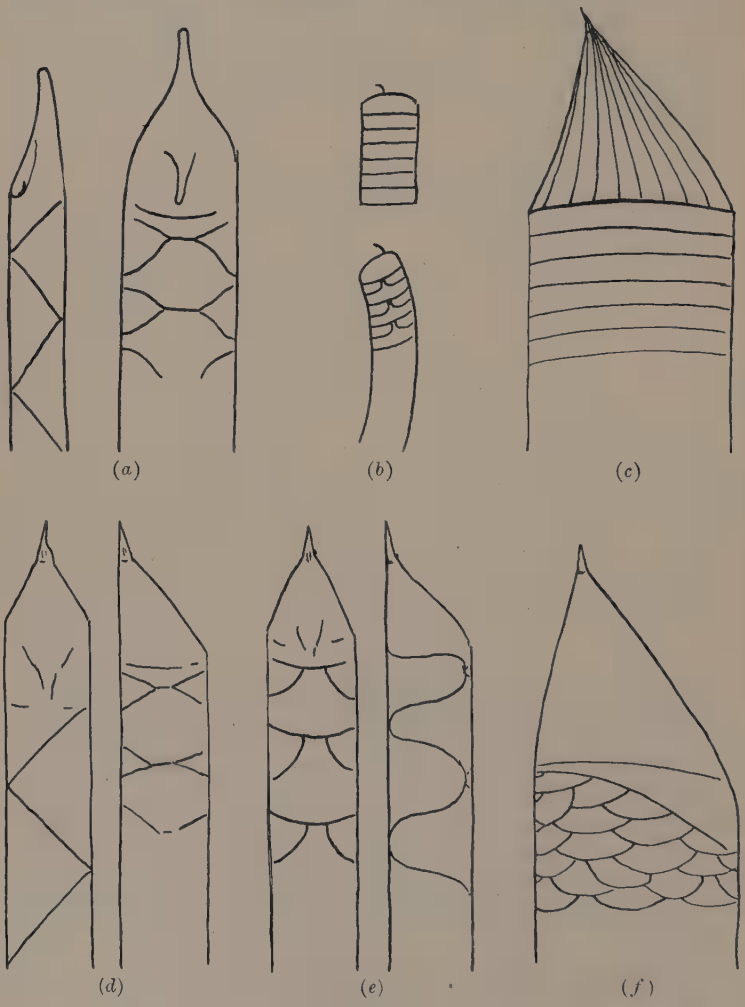


FIG. 57.—Diagram showing the different sections in *Rhizosolenia*. (*a*) *Inermes*; (*b*) *Affines*; (*c*) *Robustæ*; (*d*) *Imbricatæ*; (*e*) *Genuinæ*; (*f*) *Squamosæ*.

apex or with an excentric fine hair-like spine or process with which usually a trough-like depression or line corresponds in the sister cell. Girdle zone with numerous intercalary bands of different form and arrangement in different species. Chromatophores numerous (rarely only 2–4). Dimorphic forms occur, and these are often regarded as separate species. When, however, specimens occur with one form at one end and a different one at the other end it is thought right that these should be regarded as one species. This is the case with *R. hebetata* f. *semispina* and f. *hiemale*, which Gran (1905) considers two forms of one species and Pavillard considers as two distinct species. In the same way *R. alata* and its variety *indica* are regarded by Pavillard as distinct species and by Péragallo as two forms of one species.

Auxospores, resting-spores and microspores are known. Auxospores either at right angles to the mother-cell or longitudinal. Large maxima in the summer of rod-shaped form. The genus is, on the whole, a lover of warmth, appearing in the present area chiefly in the summer, when huge numbers of different species frequently occur. In the Mediterranean and warmer seas the maxima are often in the autumn. Most of the species are oceanic, but may occur in numbers near the coast and even reproduce there.

The genus is usually subdivided according to the form of the valve and the scale-like intercalary bands. The scheme used by Pavillard (1925) is used here.

Section I. Inermes.

Valves more or less conical, truncated, without terminal spine; scales as in Genuinæ.

Species: *R. alata* Brightw., *R. obtusa* Hensen.

Section II. Affines.

Valves rounded, not conical, furnished with a short and elongated spine. Intercalary bands collar-like.

Species: *R. delicatula* Cleve, *R. faeröense* Ostenf., *R. fragillima* Bergon, *R. Stolterfothii* Pérag., *R. cylindrus* Cleve.

Section III. Robustæ.

Valves elongated, conical, with linear ornamentation. Extremity more or less thickened, supporting a variably shaped spine. Intercalary bands collar-like.

Species: *R. robusta* Norman.

Section IV. Imbricatæ.

Two rows of lateral scale-like intercalary bands. Sutures dorso-ventral in a zigzag (the valve being orientated so that the spine is dorsal.

Species: *R. Shrubsolei* Cleve.

Section V. Genuinæ.

Two rows of dorsi-ventral scale-like intercalary bands. Lines of suture a zigzag.

Species: *R. setigera* Brightw., *R. styliformis* Brightw., *R. calcar-avis* Schultze, *R. hebetata* (Bail.).

Section VI. Squamosæ.

Intercalary bands numerous imbricated scales.

Species: *R. acuminata* (Pérag.), *R. Bergonii* Pérag. (placed by Pavillard in the Robustæ), *R. Castracanei* Pérag., *R. arafurensis*, Castr.

Section I. Inermes.

Rhizosolenia alata Brightw., 1858*a*.

(Figs. 58, 59, 60, 61.)

Gran, Nordisches Plankton, p. 56.

Cell straight, valves shortly conical, then suddenly drawn out in a tube-like, somewhat curved oblique process. At the base of the tube is a depression, surrounded by a faint border, into which the apex of the neighbouring cell fits. Scales rhombic, finely striated.

FIG. 58. — *Rhizosonelia alata* Brightw. form *genuina* Gran, 12μ across, Plymouth (M. V. L.).

FIG. 59.—*Rhizosolenia alata* Brightw. form *gracillima* Cleve, × 450. After Gran, 1905.

FIG. 61.—*Rhizosolenia alata* Brightw. form *curvirostris* Gran. After Gran, 1900*b*.

FIG. 60.—*Rhizosolenia alata* Brightw. form *indica* (Péragallo), 42μ across, Plymouth (M. V. L.).

Chromatophores numerous. Diameter 7–70μ. Oceanic, but often occurring near the coast. Temperate species. Resting spores and auxospores known (Schütt, 1893, 1896), the auxospores growing out in the same plane as the main cell, the resting spores like those of *R. setigera* (Fig. 5*d*) Mangin, 1912.

Distribution.—Davis Strait, all parts of the North Sea, Skaggerak, European and American North Atlantic, English Channel, Mediterranean, Black Sea, California, Indian Ocean, Antarctic.

Péragallo describes a very fine spine at the base of the depression where the neighbouring cell fits. Mangin (1915) is convinced that it is not there. The specimens examined by the writer agree with Mangin.

Gran (1905) recognizes four varieties or forms:

(*a*) Form *genuina* Gran. Apex almost parallel with the main axis of the cell, weakly bent. Diameter 7–15μ (Fig. 58). Oceanic.

(*b*) Form *gracillima* Cleve (= *Rhizosolenia gracillima* Cleve, 1897*a*), like the type, but narrower. Diameter 5–7μ (Fig. 59). This is a coastal form and perhaps truly neritic, occurring in the coastal waters of northern seas. Produces auxospores which are common in Danish seas, which bring it to the same size as the type. Ostenfeld (1913*a*) regards it as a variety adapted to coastal conditions, occurring chiefly in the summer. Abundant off the Brittany coast with form *indica* (Mangin, 1912).

(*c*) Form *indica* (Péragallo, 1892) = *Rhizosolenia corpulenta* Cleve, 1897*a*. This is regarded as a distinct species by Pavillard (1925) and others, but as it is seen sometimes with one end having the typical *alata* form it seems right to regard it as a variety. Péragallo found such specimens, and the present writer has also seen them at Plymouth. Cell much larger and broader than the type. Diameter 40–70μ (Fig. 60). Valve with a curved thin process.

Distribution.—Usually in warmer seas than the type,

but sometimes with it. Red Sea, Gulf of Aden, Indian Ocean, Northern seas, fairly common at Plymouth.

(*d*) Form *curvirostris* Gran, 1900*b*. Cell with process of valve drawn out in a long curve (Fig. 61). Only seen by Gran off the Norwegian coast.

Rhizosolenia obtusa Hensen, 1887.

(Fig. 62.)

Gran, Nordisches Plankton, p. 56.

Cell like *R. alata*, but with a sharply truncated apex to the drawn-out process of the valve, hardly curved at all. Oceanic.

Distribution.—Northern species. Known from the colder parts of the North Atlantic, Norwegian seas, East Greenland. Recorded from California.

Fig. 62.—*Rhizosolenia obtusa* Hensen, × 600. After Gran, 1905.

Section II. Affines.

Rhizosolenia delicatula Cleve, 1900*b*.

(Fig. 63.)

Gran, Nordisches Plankton, p. 48.

Cell cylindrical, with flat valves, slightly rounded at the edges, united in straight chains. Valve with an excentric spine which fits into a depression in the margin of the neighbouring cell. Chromatophores few, large. Diameter 14–20μ. Neritic.

Distribution.—Temperate Atlantic, English Channel, North Sea, Belgian coast, Adriatic.

Rhizosolenia faeröense Ostenf., 1899.

(Fig. 64.)

Gran, Nordisches Plankton, p. 48.

Cells loosely united in short straight chains, cylindrical, with rounded ends. Almost in the centre of the valve is a small spine that fits into the depression in the

neighbouring cell. Diameter 25–70μ ; length 50–80μ. Neritic. North temperate species.

Distribution.—Davis Strait, all parts of the North Sea, Baltic, Iceland, Faroes, Skaggerak, North Atlantic (European and American), English Channel, California ?

FIG. 63.—*Rhizosolenia delicatula* Cleve. After Péragallo, 1892.

FIG. 64.—*Rhizosolenia faerŏense* Ostenf. 25μ across, Plymouth (G. E. W.).

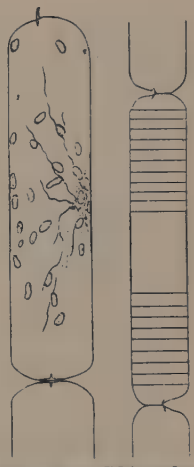


FIG. 65.—*Rhizosolenia fragillima* (Bergon) Gran. After Pavillard, 1913.

Rhizosolenia fragillima Bergon, 1903*a*, Gran.
(= *Rhizosolenia fragillissima* Bergon, 1903*a*.)
(Fig. 65.)

Gran, Nordisches Plankton, p. 49.

Cell twice or more as long as broad. Chromatophores in the middle of the cell. Otherwise like *R. faerŏense*. Diameter 20μ. Neritic. Boreal-temperate species.

Distribution.—Southern part of North Sea, Skaggerak, Atlantic coast from France to Norway (rare in Danish seas), English Channel, Mediterranean. California ? Pavillard (1913, 1925) regards this species and *R. faerŏense* as identical. Gran (1915) gives reasons for their separation on the grounds of their different distribution and time of maxima.

Rhizosolenia Stolterfothii H. Pérag., 1888.

(Fig. 66.)

Gran, Nordisches Plankton, p. 49.

Cells united in curved chains, often spiral, with flat valves rounded at the edges and having an excentric spine which fits into a depression in the neighbouring cell, and on that account is only distinct at the free ends. Intercalary bands collar-like, sometimes easily seen. Chromatophores numerous, small. Diameter 15–40μ. Neritic. Sometimes regarded as oceanic. Pavillard (1905) describes the auxospores from the Lake of Thau, Mediterranean, occurring on one day only in September after a large summer maximum. The cell breaks into two and completely empties itself into a large bladder. Mother-cell 14μ broad, new cell formed in the auxospore 80μ × 35μ.

Distribution.—Arctic seas, all parts of the North Sea, Danish seas, Skaggerak, North Atlantic (European and American), English Channel, Belgian coast, Mediterranean, California, Indian Ocean.

Rhizosolenia cylindrus Cleve, 1897*a*.

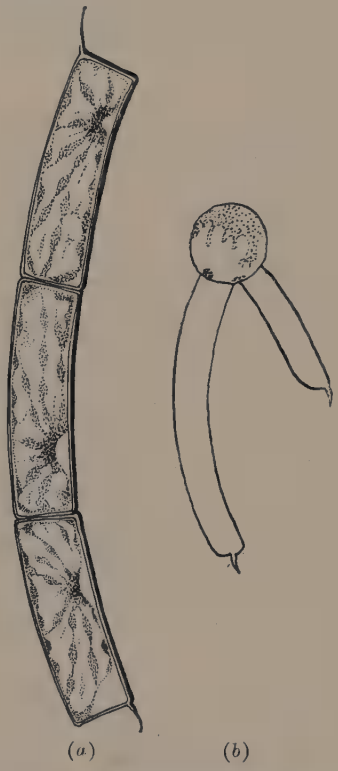
(Fig. 67.)

Gran, Nordisches Plankton, p. 49.

Cell cylindrical, with rounded or conical valves, each valve bearing a curved process, by which the neighbouring cells are united in chains. Intercalary bands numerous, ring-like. Diameter 26μ ; length 160–240μ.

Differs from *R. Stolterfothii* by its loose chains, straighter form and stronger processes. Possibly a variety.

Distribution.—Sub-tropical, Atlantic Ocean, California, rare.



(*a*) (*b*)

FIG. 66.—(*a*) *Rhizosolenia Stolterfothii* H. Pérag., 25μ across, Plymouth (G. E. W.); (*b*) auxospore formation. After Pavillard, 1905.

FIG. 67.—*Rhizosolenia cylindrus* Cleve. After Cleve, 1897*a*.

Section III. ROBUSTÆ.

Rhizosolenia robusta Norman (in Pritchard), 1861. (Fig. 68.)

Gran, Nordisches Plankton, p. 50.

Cells single or in short chains, cylindrical, with an oval section and deeply conical curved ends. Valve

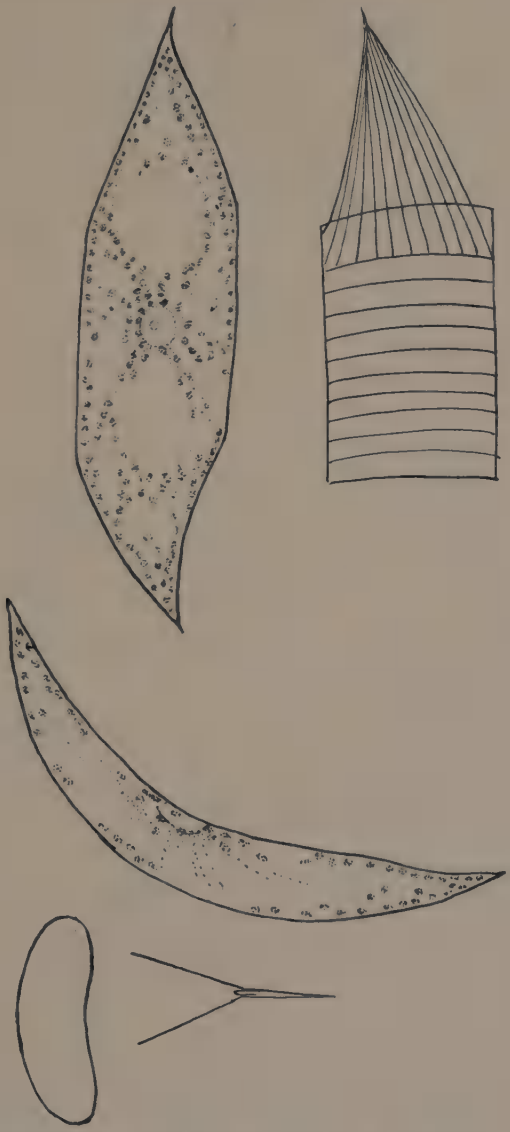


FIG. 68.—*Rhizosolenia robusta* Norman, 160μ across, Plymouth (M. V. L.).

with a small hollow apical process with a short spine. Intercalary bands numerous, collar-like. Chromatophores numerous. Diameter *ca.* 160–170μ. Oceanic.

Distribution.—All parts of the North Sea, Skaggerak, English Channel, Irish Sea, North Atlantic (European and American), Belgian coast, Mediterranean, American North Pacific Coast.

This species is commoner in the English Channel than it used to be, especially in autumn, and has only in recent years been observed off Port Erin, Isle of Man.

Section IV. Imbricatæ.

Rhizosolenia Shrubsolei Cleve, 1881.

(Fig. 69.)

Gran, Nordisches Plankton, p. 52.

Cell long and narrow, single or united in chains, roundly cylindrical or slightly compressed at the sides. Valves oblique, pointed, the apical process hollow nearly all the way up with very small wings at the base, regularly decreasing in size until the point is reached, the small wings running up about a third of the spine and not extending on to the valve itself. Mangin (1913) has distinguished this form of spine and that of *R. styliformis* in a very exact manner. Intercalary bands scale-like with striations formed of rows of minute puncta, the bands arranged in two long rows, each band being a triangular scale with the corner pointing in such a way that they form an imbricating row on each side of the apex. Chromatophores numerous, small. Nucleus suspended in the central cytoplasm. Diameter 10–40μ. Neritic. Sometimes regarded as oceanic.

Distribution.—Much the same as *S. Stolterfothii*, but more northerly. Known from all parts of the North Sea, Skaggerak, Baltic, North Atlantic (European and American), English Channel, Belgian coast, Mediterranean.

Auxospores described by Meunier (1915) at right angles to the mother-cell (Fig. 5*c*).

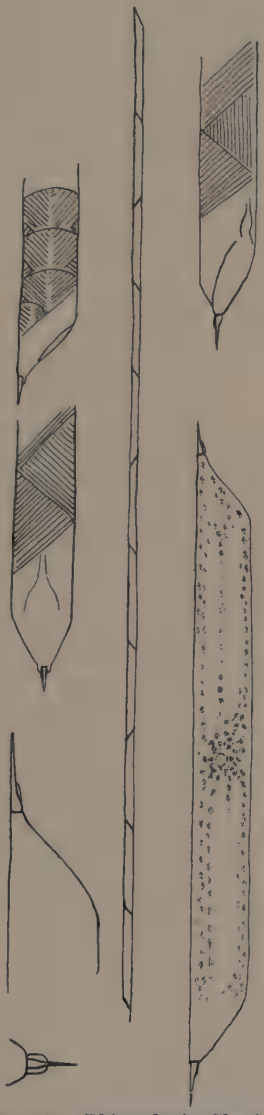


FIG. 69.—*Rhizosolenia Shrubsolei* Cleve, 22μ across, Plymouth (M. V. L.).

FIG. 70.—*Rhizosolenia setigera* Brightw., 6μ across, Plymouth (G. E. W.).

Pavillard (1925) and Mangin (1913) are inclined to separate the form *imbricata* from this species, as does also Forti (1922). In that case the true more northerly *R. Shrubsolei* would be small, about 4–21μ, and the valve elongated, whilst *R. imbricata*, more southerly, would be larger, 20–40μ, with a lower valve.

Section V. Genuinæ.

Rhizosolenia setigera Brightw., 1858*a*.

(Fig. 70.)

Gran, Nordisches Plankton, p. 53.

Cells cylindrical, straight, valves regularly conical, drawn out lengthwise, only slightly oblique. Apical process solid at the base, bearing a very long fine straight spine. Intercalary bands two long rows pointing towards the apex, not at the sides as in *R. Shrubsolei*. Numerous chromatophores. Resting spores in specimens from the Welsh coast observed by the present writer (Fig. 5*d*), also described by Meunier (1915), smooth, cylindrical, one in each cell, rounded at one end, almost flat at the other. Gran describes two in each cell. Diameter of cell 6–25μ. Cold water form. Living at the bottom in unfavourable circumstances forming the resting spores. Maximum in early spring or in summer. Resting spores after the spring maximum. Neritic. North temperate species.

Distribution.—Davis Strait, all parts of the North Sea, Skaggerak, Baltic, English Channel, Belgian coast, Mediterranean, North Atlantic (European and American), Vancouver and California.

Rhizosolenia styliformis Brightw., 1858*a*.

(Fig. 71.)

Gran, Nordisches Plankton, p. 54.

Cells cylindrical, never compressed. Valves obliquely pointed as in *R. Shrubsolei*, but rather more sharply. Apical process pointed with a long cavity penetrating

the tip of the valve, with two wing-like expansions beginning on the valve and finishing near the base of the process. Valve with distinct mark for the valve of the sister-cell, both for the spine and wings. Intercalary bands scale-like with very fine reticulated sculpture, arranged as in *R. setigera*. Chromatophores very numerous. Meunier (1910) describes resting spores similar to those of *R. setigera*. Diameter of cell 22–102μ. Oceanic. Likes a high salinity.

Distribution.—Arctic seas, Davis Strait, all parts of the North Sea, Norwegian seas, Skaggerak, Baltic (rare), North Atlantic (European and American), English Channel, Belgian coast, Vancouver, California, West Indies, Antarctic.

Rhizosolenia calcar-avis Schultze, 1858.

(Fig. 72.)

Gran, Nordisches Plankton, pp. 54–55.

Cells like *R. styliformis*, but the valves not so oblique, more regularly conical and curved at the apex. Apical process without wings, curved like a claw. Depression in the valve of the sister-cell more indistinct than in *R. styliformis*. Diameter 30–65μ. Length 0·5–·7 mm. Oceanic ? Tropical, perhaps neritic.

Distribution.—Southern part of North Sea, Danish seas, Skaggerak, Finland, North Atlantic (European and American), Mediterranean, California, Indian Ocean.

Rhizosolenia hebetata (Bail.), 1856.

(Fig. 73.)

Gran, Nordisches Plankton, p. 55.

A dimorphic species, appearing according to locality and season as two very different forms. Occasionally a cell has one form at one end and the other form at the other end. Oceanic.

(*a*) Form *semispina* (Hensen) = *Rhizosolenia semispina* Hensen. Valve longitudinally drawn out, process

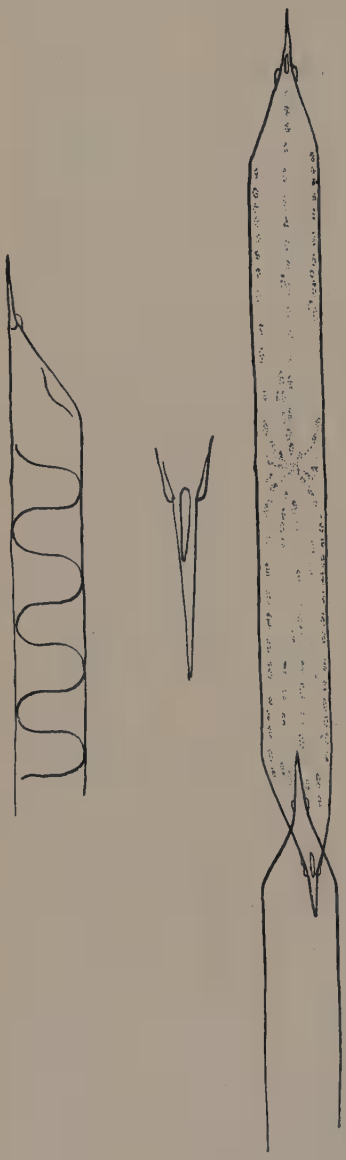


FIG. 71.—*Rhizosolenia styliformis* Brightw., 64μ arcoss, Plymouth (M. V. L.).

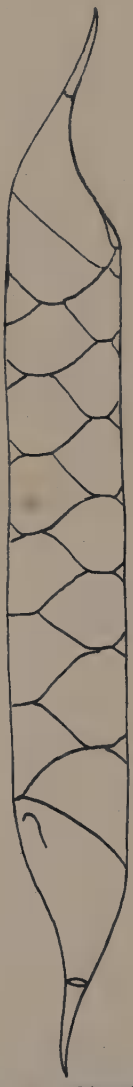


FIG. 72.—*Rhizosolenia calcar-avis* Schultze. After H. Péragallo, 1892.

FIG. 73.—*Rhizosolenia hebetata* (Bail.). (*a*) Form *semispina* (Hensen), 10μ across, Plymouth (G. E. W.); (*b*) form *hiemalis* Gran, 12μ across, Plymouth (M. V. L.).

hollow at the base and ending in a long curved hair-like spine. Diameter 4·5–12·5μ. Boreal-Arctic form.

Distribution.—Arctic seas, E. Greenland Sea, all parts of the North Sea, Baltic, Skaggerak, English Channel, Belgian coast, Mediterranean, California, Antarctic. Usually a warm water and summer form.

(*b*) Form *hiemalis* Gran = *R. hebetata* Bailey. Cell straight, valves longitudinally drawn out; apical process thick, solid, except for a small hollow, with a rounded spine. Junction between the scale-like intercalary bands distinct. Chromatophores numerous. Usually a winter and cold water form.

Distribution.—Known from the Arctic Seas, Davis Strait, all parts of the North Sea, Skaggerak, North Atlantic (European and American), English Channel.

Pavillard (1925) regards these two forms as distinct species, of which the first only is present in the Mediterranean. As, however, elsewhere it has been found with one form at one end and the other form at the other end, it seems that it should be regarded as only one species.

Section VI. Squamosæ.

Rhizosolenia acuminata (H. Pérag.), 1892, Pav. 1925. (Fig. 74*a*.)

(= *R. acuminata* form *debilis*.

Gran, Nordisches Plankton, p. 50–51.)

Intercalary bands scale-like, in at least four rows. Cell straight with a long conical valve. Valve with a small process, which has a small elongated hollow at the base, but no wings. Cell-wall very strong. Chromatophores small, numerous. Diameter 35–50μ. Length 0·6–0·85 mm. Oceanic.

Distribution.—In the southern part of this area (to about 60° North latitude), Mediterranean, tropical and sub-tropical Atlantic, Pacific.

Rhizosolenia Bergonii H. Pérag., 1892.

(Fig. 74*b*.)

Gran, Nordisches Plankton, p. 51.

Valve narrowly conical, apex thick-walled, with a small basal hollow. Intercalary bands scale-like, with

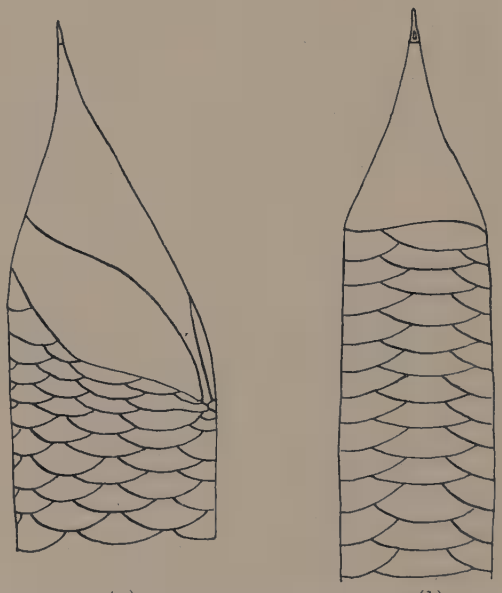


Fig. 74.—(*a*) *Rhizosolenia acuminata* (H. Péragallo); (*b*) *Rhizosolenia Bergonii* H. Péragallo. After H. Péragallo, 1892.

regular bow-shaped margins, in four or five rows. Auxospores observed by Schütt (1893*a*), but Gran (1905) is not sure if the species was correctly identified. Diameter 100μ. Oceanic.

Distribution.—Atlantic Ocean (northerly limit about 48° north latitude), Mediterranean, Bay of Biscay.

Rhizosolenia Castracanei H. Pérag., 1888.

(Fig. 75*a*.)

Gran, Nordisches Plankton, pp. 51–52.

Valve conical with oblique apex. Intercalary bands with wavy borders in numerous rows. Cell-wall strong. Diameter *ca.* 150μ. Length 600μ. Oceanic.

Distribution.—Atlantic Ocean (northern limit about 48° north latitude), Mediterranean.

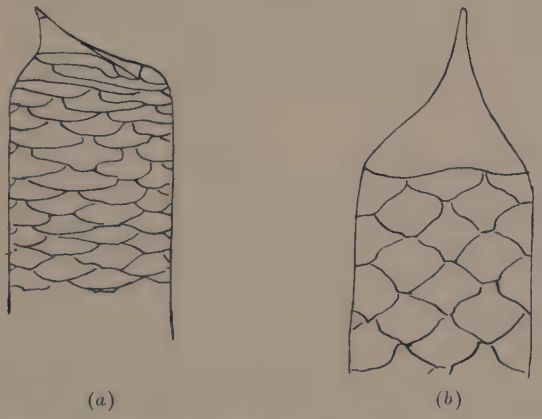


Fig. 75.—(*a*) *Rhizosolenia Castracanei* H. Péragallo; (*b*) *Rhizosolenia arafurensis* Castr. After H. Péragallo, 1892.

Rhizosolenia arafurensis Castr., 1886.

(Fig. 75*b*.)

Gran, Nordisches Plankton, p. 52.

Valve conical, with hollow process abruptly truncated at the top. Scales more or less rhombic, with wavy margins in several rows. Cell-wall strong. Diameter *ca.* 120μ. Oceanic.

Distribution.—Indian Ocean, Atlantic Ocean (northerly limit about 45° north latitude).

Group C. BIDDULPHIOIDÆ Schütt, 1896.

Cells with two or more poles. Cross-section oval or polygonal, very rarely circular.

Family 1. CHÆTOCERACEÆ Schröder, 1911.

Cells with two poles, united in chains by bristles, one on each side of the valve, each one fused to the corresponding bristle on the neighbouring cell, leaving gaps (apertures) between the cells. Cross-section oval, sometimes nearly or completely circular.

Genus **CHÆTOCEROS** Ehr., 1844.

(Fig. 76.)

Cell with oval section, sometimes nearly, or rarely completely, circular, in girdle view quadrangular with straight sides and concave, flat, or weakly convex ends. Valve consisting of a more or less flat end surface (the *valve surface*) and a cylindrical part (the *valve mantle*), which are bound together without a seam. Valve bearing at each end of the long axis (*apical axis*) on the corners, a long thick or thin *bristle*, sometimes called an *awn*. The opposite bristles of neighbouring cells touch one another near their origin, usually directly, sometimes by a bridge, and are firmly fused together. By the fusion of the bristles the cells are formed into chains, usually with large or small *apertures* or *foramina* between the cells. In some species the length of the chain is limited by the formation of special end-cells, their outer bristles not being connected with neighbouring cells and differing from the others, often being shorter and thicker and more nearly parallel with the chain axis. These end-cells probably serve a directive purpose when the chain floats. Cell-wall formed of two valves and one or two girdle-bands. Intercalary bands present in some species, but usually difficult to see without special methods. The valve or chain axis runs

through the valves from centre to centre. The cytoplasm forms either only a thin sac along the cell-wall or it fills the greater part of the inside. Nucleus against the cell-wall or central. Chromatophores one to several, small or large. Resting spores formed in most of the neritic species, usually in the cylindrical part near the girdle band of the mother-cell, one to each cell. The valves of the spores are often armed with spines or spicules, sometimes only on one valve, sometimes on both, rarely also at the sides. The younger resting spores are often smooth, the armature coming on later when the spores are fully formed. Auxospores are known only in rare cases, the contents of a cell emptying itself at the side in a large bladder, inside which the new daughter-cell is formed (*C. compressus*, *C. exospermus*). In a few species resting spores are formed in lateral auxospores (*C. Eibenii*, *C. constrictus*, *C. pseudocrinitus*).

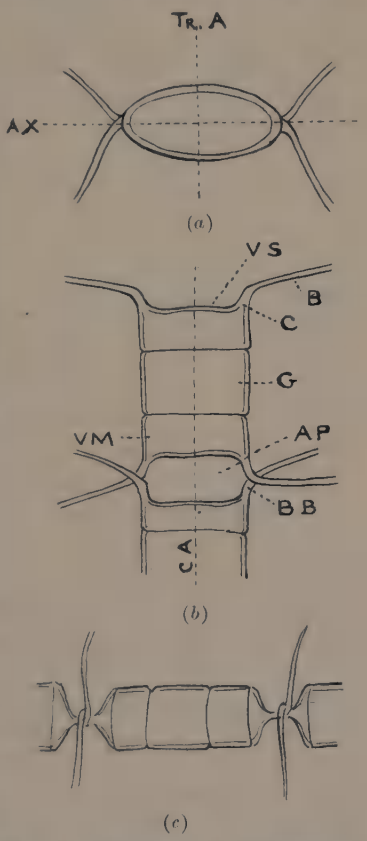


FIG. 76.—Diagram of *Chætoceros* (G. E. W.). (*a*) Valve view; (*b*) broad girdle view; (*c*) narrow girdle view. AP, aperture; AX, apical axis; B, bristle; BB, base of bristle; C, corner of valve; CA, chain axis; G, girdle; TR. A, transapical axis; VM, valve mantle; VS, valve surface.

There may be great differences in the chains of the same species from different localities, and at different times of year. Gran (1912) has shown two distinct forms of *C. decipiens* followed from warm to cold water with a perfect

gradation between, the two extremes being almost like different species.

This is the largest genus of the truly planktonic forms, over 100 species being known. There are a few littoral species amongst which is *C. armatus* West., which occurs sometimes in masses on our coasts at low-water mark. Certain forms are oceanic, especially those belonging to the sub-genus *Phæoceros* Gran, but by far the greater number are neritic. The genus was first instituted by Ehrenberg, who describes several species. It has since held the attention of many workers, chief of whom are Cleve, Grunow, Castracane, Schütt, Lauder, Brightwell, Bailey, Schröder, Jörgensen, Ostenfeld and Gran, and later, besides the four last-mentioned, Péragallo, Meunier, Mangin and Pavillard.

In 1897*a* Gran divided the genus into two sub-genera, *Phæoceros* and *Hyalochæte*, which are still in use. Ostenfeld (1903) subdivided these into sections, which were emended by Gran (1905), most of the emendations being retained by Ostenfeld (1913*a*) and are still in use. It is thus chiefly owing to Gran and Ostenfeld that there is any system at all in this large genus. Meunier (1910, 1915) greatly enlarged our knowledge of the genus by his drawings and special observations on auxospores and resting spores. Pavillard (1921) was the first to describe auxospores with resting spores in the sub-genus *Phæoceros*, finding them in *C. Eibenii*. These have later been found by the writer in the English Channel. Gran (1915) had already described such spores in the sub-genus *Hyalochæte*. Mangin (1915, '19, '22) cleared up some of the difficult species of the *Phæoceros* group and compared the Antarctic with our northern forms. Ostenfeld (1912) specialized on the species living singly (*simplicia*), and investigated all the species from Danish seas (1913*a*). Gran (1915) summarized our knowledge of the species in the area of the International Fisheries Investigations, and with Yendo (1914), in describing the Japanese species, added much to our knowledge of the group, besides classifying

and describing our northern species in 'Nordisches Plankton.'

The genus is subdivided as follows:

Sub-genus **PHÆOCEROS** Gran, 1897*a*.

With numerous chromatophores which penetrate into the bristles. Mostly oceanic. Resting spores only known in *C. Eibenii*.

Section I. Atlantica Ostenfeld, 1903.

The direction of all the bristles alike (except the terminal bristles, which are distinctly different from the others) in one plane. A small spine is usually present in the centre of the valve.

Species: *C. atlanticus* Cleve, *C. neapolitanus* Schröder, *C. Janischianus* Castr., *C. polygonus* Schütt.

Section II. Borealia Ostenfeld, 1903.

Bristles usually diverging in all directions, the directions on one valve often differing from those on the other. Usually no spine in the centre of the valve.

Species: *C. densus* Cleve, *C. Eibenii* (Grun.) Meunier, *C. borealis* Bail., C. *Glandazi* Mangin, *C. coarctatus* Lauder, *C. convolutus* Castr., *C. convexicornis* Mangin, C. *concavicornis* Mangin, *C. danicus* Cleve, *C. tetrastichon* Cleve.

Sub-genus **HYALOCHÆTE** Gran, 1897*a*.

Bristles thin, without chromatophores in them. Chiefly neritic. Resting spores known in most of the species.

Section I. Oceanica Ostenfeld, 1903, emended.

Chromatophores rather large, 6–10. Bristles coalesced along a short portion of their length. No resting spores known. Oceanic.

Species: *C. decipiens* Cleve.

Section II. Dicladia (Ehr.) Gran, 1905, emended.

Like *Oceanica*, but with the bristles not always coalesced for a portion of their length, with resting spores having two horns armed with small branches on the primary valves. Neritic. The section takes its name from these two horns, Ehrenberg having founded a genus from the resting spore alone; for this reason the present writer has separated the section from *Oceanica* containing *C. decipiens*, which is not known to have any spores.

Species: *C. mitra* (Bail.), *C. Lorenzianus* Grun.

Section III. Cylindrica Ostenfeld, 1903.

Valve nearly circular. Apertures very narrow. Chromatophores small, numerous. Terminal bristles not thicker than the others. Resting spores situated about the middle of the cells, smooth or with spines.

Species: *C. teres* Cleve, *C. Lauderi* Ralfs.

Section IV. Compressa Ostenfeld, 1903.

Cells compressed, chromatophores numerous; intercalary bristles thickened and twisted, sometimes occurring in between the normal bristles. Resting spores smooth or with a row of spicules.

Species: *C. compressus* Lauder.

Section V. Protuberantia Ostenfeld, 1903.

Two chromatophores, each with a large pyrenoid situated in a protuberance in the middle of the valve surface. Resting spores with two long horns.

Species: *C. didymus* Ehr.

Section VI. Constricta Ostenfeld, 1903.

Chromatophores one or two. Cells more or less constricted. Girdle at least one third of the length of the cell, terminal bristles mostly thicker than the others. Resting spores about the middle of the cells, with numerous spines on both valves.

Species: *C. constrictus* Gran.

Section VII. Stenocincta Ostenfeld, 1903.

One chromatophore. Girdle narrow, not one-third of the length of the cell. Aperture rather narrow. Terminal bristles thicker than the others, curved, and for the most part diverging greatly. Resting spores about the middle of the cell with numerous spines on both valves.

Species : *C. affinis* Lauder.

Section VIII. Laciniosa Ostenfeld, 1903.

Chromatophores one or two, girdle rather long. Aperture large, terminal bristles mostly thicker than the others, not diverging greatly. Resting spores smooth or with minute spines on the primary valve, not in the middle of the cell.

Species : *C. laciniosus* Schütt, *C. brevis* Schütt.

Section IX. Diadema (Ehr.) Ostenfeld, 1903. Gran emended 1905.

One chromatophore. Chains long with conspicuous end bristles ; primary valve of resting spore with branched process or crown of spines, or, sometimes, smooth. Sometimes both valves armed.

Species : *C. diadema* (Ehr.), *C. coronatus* Gran, *C. holsaticus* Schütt, *C. seiracanthus* Gran, *C. difficilis* Cleve.

Section X. Diversa Ostenfeld, 1903.

Short rigid chains whose end-bristles are less spread out than a special pair of bristles in the middle of the cell. One chromatophore.

Species : *C. furca* Cleve, *C. diversus* Cleve.

Section XI. Brevicatenata Gran, 1905.

One or two chromatophores. Short straight chains, with few joints. End-bristles more or less different from the others, but very thin. Mostly small or very small forms.

Species: *C. similis* Cleve, *C. subtilis* Cleve, *C. Wighami* Brightw., *C. perpusillus* Cleve, *C. filiformis* Meunier, *C. exospermus* Meunier, *C. karianus* Grun., *C. fragilis* Meunier, *C. crinitus* Schütt, *C. pseudocrinitus* Ostf., *C. ingolfianus* Ostf.

Section XII. Curviseta Ostenfeld, 1903. Gran emended 1905.

One chromatophore, bristles curved, all bent in one direction; chains usually curved, without special end-cells.

Species: *C. curvisetus* Cleve, *C. debilis* Cleve, *C. pseudocurvisetus* Mangin, *C. adhærens* Mangin, *C. imbricatus* Mangin.

Section XIII. Anastomosantia Ostenfeld, 1903.

Bristles united by a bridge.

Species: *C. externus* Gran.

Section XIV. Furcellata Ostenfeld, 1903.

One chromatophore; terminal bristles not differentiated. Resting spores occurring excentrically in the mother-cell, lying close together two and two, bearing thick coalesced bristles and with smooth valves or with short spines.

Species: *C. scolopendra* Cleve, *C. cinctus* Gran, *C. furcellatus* Bail., *C. tortissimus* Gran.

Section XV. Socialia Ostenfeld, 1903.

Chains curved, embedded in mucilage forming irregularly spherical colonies. One chromatophore. Resting spores smooth or with small spines.

Species: *C. socialis* Lauder, *C. radians* Schütt.

Section XVI. Simplicia Ostenfeld, 1903.

Cells living singly or two or three together.

Species: *C. gracilis* Schütt, *C. septentrionalis* Oestrup, *C. simplex* Ostf., *C. ceratosporus* Ostenf.

As is shown above, Ostenfeld and Gran base the classification of the genus on the form of the cells, form and direction of the bristles, form of aperture, number of chromatophores and form of the resting spores. These last may be very variable, and in some sections there are placed species whose resting spores are very unlike, the other characters perhaps warranting their being placed together until more is known of them. Thus *C. seiracanthus* has resting spores which are entirely unlike *C. diadema* although spinose, and in *C. difficilis* they are smooth, and yet these are all placed by Gran in the section DIADEMA. They are left there until more details are known which may show that they are not so closely related. In the sub-genus *Phæoceros* the two sections are not very well separated, and we have certain forms in the first section which do not show central spines on the valves and these are sometimes present in the second section, whereas in some that are placed in the second section the bristles appear to be quite regular and not going in all directions. At present it, however, appears convenient to separate them into these recognized sections until more is known about them.

Sub-genus **PHÆOCEROS** Gran, 1897*a*.

Mostly oceanic and liking a high salinity. Chromatophores numerous, extending into the bristles. No resting spores known except in *C. Eibenii*.

Section I. ATLANTICA.

Chætoceros atlanticus Cleve, 1873*a*.

(Fig. 77.)

Gran, Nordisches Plankton, pp. 64–65.

Chains straight, not twisted. Cells in broad girdle view oblong. Valves with a small spine in the centre of each cell. Cells divided by narrow constrictions into three zones usually equal, the middle zone consisting

of the girdle bands. Bristles springing from a little way within the valve margin. End-bristles always shorter than the others, at first diagonal, further out bent in so that the points are about parallel with the chain axis. The remaining bristles are usually almost straight,

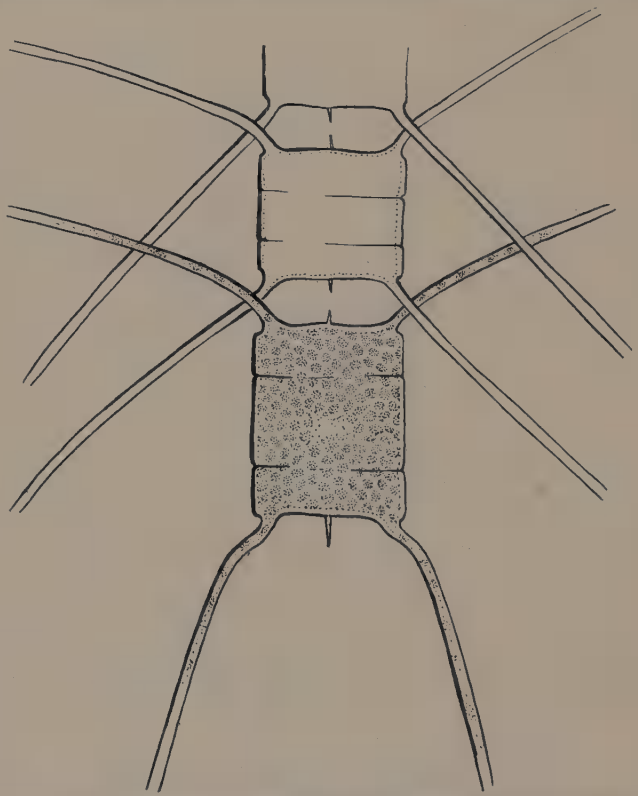


FIG. 77.—*Chætoceros atlanticus* Cleve, 30μ across, North Atlantic, "Scotia" material (G. E. W.).

cross one another and are armed with small spines. Diameter 15–40μ. Oceanic. Arctic and boreal. Likes cold water and a high salinity.

Form *audax* (= *Chætoceros audax* Schütt, 1895) Gran, 1904, occurs singly with bristles more curved and inclining towards one another at their extremities.

Distribution.—North Atlantic (European and American) and Arctic Oceans and neighbouring seas, Davis Strait, North Sea, Belgian coast only occasionally, California. In Japanese seas slightly different from the Atlantic form.

Chætoceros neapolitanus Schröder, 1900*a*.

(Fig. 78.)

Gran, Nordisches Plankton, p. 65.

Chains narrower than in *C. atlanticus*, the basal part (before fusion) of the bristles longer, being greater than the diameter of the cell. Central spine present. Diameter 13μ. Oceanic.

Distribution.—Northern part of North Sea, Mediterranean, Japanese seas, California.

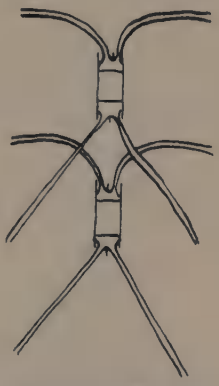


Fig. 78.—*Chætoceros Neapolitanus* Schröder. After B. Schröder. Pavillard, 1925.

Chætoceros Janischianus Castr., 1886.

(= *Chætoceros dichæta* Ehr. in Gran, Nordisches Plankton, p. 66.)

(Fig. 79.)

Valves rounded, the bristles arising rather far inside the valve margin, their bases very long (to 16μ), at first parallel with the chain axis, then bent outwards. From the fusing place outwards all the intermediate bristles are at right angles to the chain axis so that half the bristle is parallel to the chain axis, the other half parallel to the transapical axis on both sides of the chain. Terminal bristles at the base parallel with the chain axis, further out bent, then bent again. Diameter 20–45μ. Oceanic.

Schüssng (1915) has separated this species from the *C. dichæta* of Ehrenberg, which is apparently not identical with this one, being a more southerly form with very distinct central spine in the valve, whereas

none is described or figured in the present species. Mangin (1915), however, thinks the two species are identical.

Distribution.—Atlantic Ocean. In the north very rare. Antarctic Ocean, California.

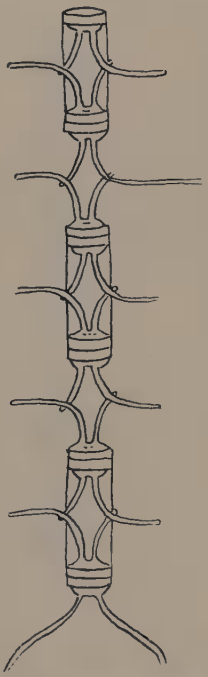


Fig. 79.—*Chætoceros Janischianus* Castr. After Castracane, 1886.

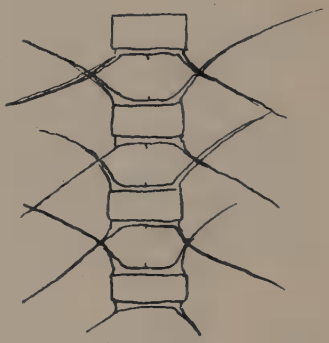


Fig. 80.—*Chætoceros polygonus* Schütt. After Cleve, 1897c.

Chætoceros polygonus Schütt, 1895.

(Fig. 80.)

Gran, Nordisches Plankton, pp. 66–67.

Cells in broad girdle view oblong, valves flat with a small spine in the centre of each. Bristles springing from near the margin. Basal part of the bristle 4–8μ long, directed diagonally outwards. Outer part perpendicular to the chain axis. Diameter 12–15μ. Oceanic.

Distribution.—Tropical and sub-tropical Atlantic.

Section II. Borealia.

Chætoceros densus Cleve, 1901*a*.

(Fig. 81.)

Gran, Nordisches Plankton, p. 67.

Chains straight, not twisted; length of cell 18–30μ. Cells close together, aperture small, but always distinct. Valves weakly rounded. Valve mantle low, hardly one-third of the height, girdle marked off distinctly by a constriction from the valve mantle. Bristles relatively thick at the base, armed with small spines beginning some way from the base, springing from the inside of the valve margin, united almost at once and exactly in the apical plane, perpendicular to the chain axis or more or less bent towards one end of the chain. End-cells different from the others, the outer valve either strongly rounded with bristles springing from near the centre, or flat with the bristles springing from near the margin almost parallel with the chain axis. Diameter 10–40μ. Oceanic, but often occurring near the coast. Likes a high salinity. Maximum usually in spring and autumn. Often in large quantities. Temperate species.

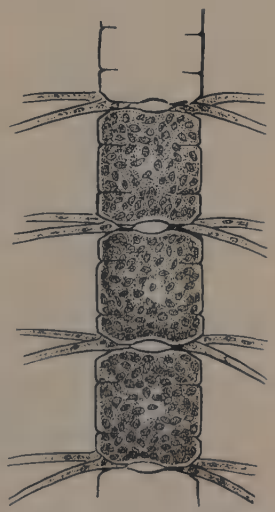


Fig. 81.—*Chætoceros densus* Cleve, 20μ across, Plymouth (G. E. W.).

Distribution.—Arctic seas, widely distributed southwards, all parts of the North Sea, Norwegian and Danish seas, Baltic, North Atlantic (European and American), English Channel, Belgian coast, Mediterranean, Japan, California.

Chætoceros Eibenii (Grun.), Meunier, 1915.

(Figs. 82, 5*b*.)

Meunier, 1913, p. 15.

Very like *C. densus* and *C. boreale*, in between the two. Inconspicuous spine in the valve centre, usually only seen in valve view, in a slight depression. Apertures oval, much wider than in *C. densus*. Diameter 30–45μ ;

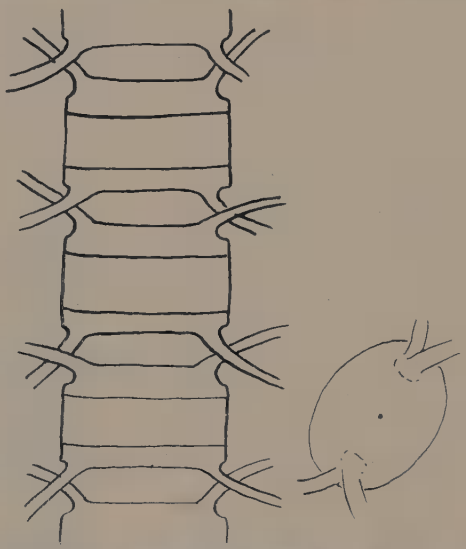


Fig. 82.—*Chætoceros Eibenii* (Grun.) Meunier, 45μ across, English Channel (M. V. L.).

length 22–24μ. Pavillard (1921) has shown collar-like intercalary bands and described lateral auxospores developing resting spores inside them. The auxospores, which have also been found by the present writer in specimens from the Channel, are formed as large bladder-like outgrowths from the girdle region growing out laterally. Each auxospore is rounded at the top with straight sides and is attached to the parent cell by a stalk. Those from the Channel are rather more rounded than in Pavillard's specimens. The resting spores

inside are of a convex lens shape, the primary valve much rounded, the lower nearly flat, those from the Channel less flat than in Pavillard's specimen. Pavillard (1921) and Meunier (1915) both describe microspores.

This species has probably been much confused with *C. densus*. Neritic ?

Distribution.—Belgian and Brittany coasts, English Channel, Mediterranena.

Chætoceros borealis Bailey, 1854.

(Fig. 83.)

Gran, Nordisches Plankton, p. 73.

Chains straight, 14–46μ broad. Valves alike. Mantle high. Girdle zone rudimentary. Valve surface somewhat convex with sharp keel between surface and

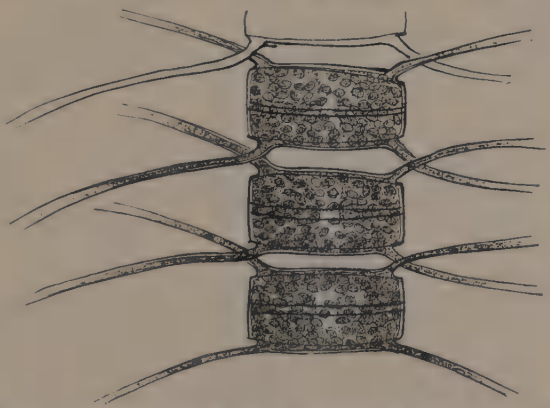


Fig. 83.—*Chætoceros borealis* Bailey, 40μ across, Plymouth (G. E. W.).

mantle. Bristles springing from inside the margin, with a distinct basal part directed diagonally outwards, from the point of fusion outwards perpendicular to the chain axis, or bending a little towards one or other end of the chain. Bristles of end-cells almost perpendicular to the chain axis. The bristles increase in thickness from the base outwards and are armed with strong spines for the greater part of their length. Apertures

always distinct, larger than in *C. densus*, *ca.* $\frac{1}{3}$ height of cell, hexagonal or oval, always broadest in the middle between the two cells. Likes cold water and a lower salinity than *C. atlanticus*. Maximum chiefly in spring. Oceanic. Arctic and northern temperate form.

Distribution.—Arctic Seas, Davis Strait, Norwegian seas, all parts of the North Sea, Baltic, Skaggerak, English Channel, North Atlantic (European and American), Pacific America, Japan. Rarely on Belgian coast. Ostenfeld (1910) has described forms with aborted bristles from the East Greenland Sea.

Chætoceros Glandazi Mangin, 1910.

(Fig. 84.)

Mangin, 1910, 1912.

Straight chains, cells 20–30μ high, 15–20μ broad. The centre of each valve prolonged into a process which

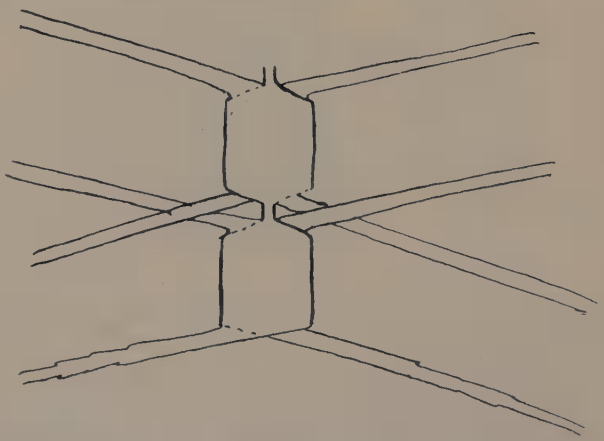


Fig. 84.—*Chætoceros Glandazi* Mangin, 20μ across. After Mangin.

meets its fellow opposite, forming a canal. Bristles long and straight, with chromatophores extending into them, inserted in the middle of the valve, the terminal

bristles denticulated, the others smooth. Numerous chromatophores (Mangin). Neritic ?

Distribution.—Open sea from the Sables d'Orlonne to Lorient, France. Rare. Pavillard (1911) regards this species as synonymous with *C. rostratus* Lauder, but Mangin (1912) shows that they are almost certainly different.

Chætoceros coarctatus Lauder, 1864.

(Fig. 85.)

Gran, Nordisches Plankton, p. 68.

Differs from *C. densus* by having a rather higher valve mantle and the bristles differing in being armed from near the base outwards with thick spines. Some of the thicker bristles are strongly bent about the middle. Oceanic. Tropical form.

Distribution.—Tropical Indian and Atlantic Oceans (European and American), Antarctic. Northerly limit about 47° north latitude.

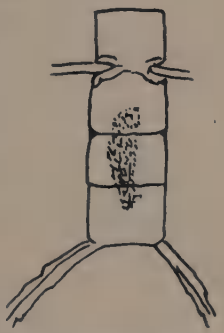


Fig. 85.—*Chætoceros coarctatus* Lauder. After Cleve, 1901*b*.

Chætoceros convolutus Castr., 1886.

(Fig. 86.)

Gran, Nordisches Plankton, p. 69.

Chains straight, or more or less twisted, 11–30μ broad. Valves unlike, the upper rounded, the lower flat. Valve mantle about one-third the height of the cell, the middle third being formed by the girdle zone. Junction between the valve and girdle-band conspicuous. Bristles relatively thin, thinner than in *C. densus*; armed more strongly than in that species, but less so than in *C. concavicornis* and *C. borealis*, those of the upper valve springing from near the centre, those from

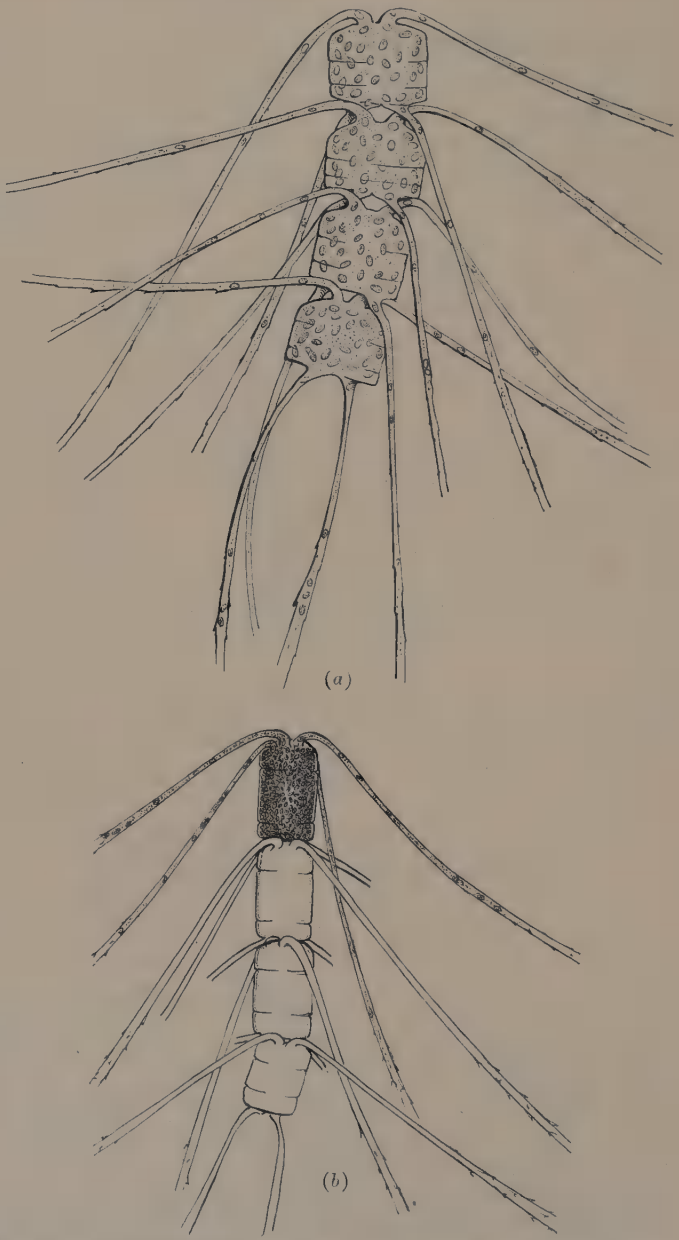


FIG. 86.—*Chætoceros convolutus* Castr. (*a*) 30μ across; (*b*) 20μ across (G. E. W.).

the lower valve from nearer the valve margin. From the starting point outwards they curve over to the opposite side, and from the point of fusion all are more or less strongly bent towards the lower end of chain. Apertures between the cells partly covered by the bristles. Likes a low temperature and a high salinity. Oceanic. Arctic and boreal form.

Distribution.—Arctic Seas, Davis Strait, all parts of the North Sea, Norwegian Sea, Skaggerak, North Atlantic, English Channel, Mediterranean. Rare on Belgian coast. California.

Chætoceros convexicornis Mangin, 1919.

(= *Chætoceros peruvianus* Gran, Nordisches Plankton, p. 70. Not *C. peruvianus* Brightwell, 1856.)

(Fig. 87.)

Single cells, length and breadth *ca.* 17–30μ. Valves very unlike, the upper with rounded surface, and almost

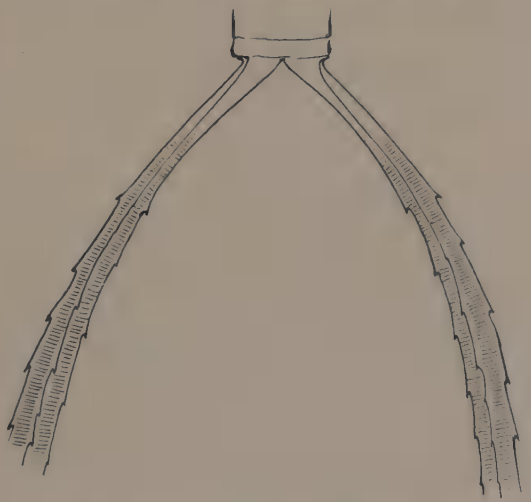


Fig. 87.—*Chætoceros convexicornis* Mangin, 18μ across, Arctic Sea (G. E. W.)

centrally springing bristles, the lower with a flat surface and the bristles springing from near the margin. Valve

mantle in both valves high. Girdle zone weakly developed, usually hardly a quarter of the height of the cell. Bristles very thick from the base outwards, becoming still thicker to the outside, where they are angular and armed with strong spines, curving outwards so that the outside outline is convex. Oceanic. Tropical.

Distribution.—Northern part of the North Sea, North Atlantic (European and American), English Channel, Mediterranean.

This is also the *C. peruvianus* of Pavillard (1925). Mangin (1919) has shown clearly that this is not the same as Brightwell's original species, which was described by him from tropical material (1856–58), and the northern species was re-named by Mangin *Chætoceros convexicornis*.

C. saltans Cleve (Pavillard, 1925) seems to be a variety of *C. convexicornis*.

Chætoceros concavicornis Mangin, 1917, 1919.

(= *Chætoceros criophilus* Gran, Nordisches Plankton, pp. 71–72. Not *C. criophilus* Castracane, 1886.)

(Fig. 88.)

Cells in straight broad chains, 12–34μ broad, or single cells. Valves very unlike, the upper part with a higher valve mantle, rounded surface and bristles springing from near the centre, the under with a rather lower valve mantle, flat surface and bristles springing from near the margin. Valve mantle completely cylindrical, without any narrowing. Girdle zone rudimentary. Bristles all bent towards the lower end of the chain, curving inwards, so that the outside outline is concave, thickly beset with small spines, thicker further out, with larger, more outstanding spines. Apertures always distinct, above broad, below narrow. Oceanic. Boreal-Arctic form, rarely found as far south as the English Channel and the Belgian coast.

Distribution.—Arctic Seas, Norwegian seas, all parts of the North Sea, North Atlantic (European and

FIG. 88.—*Chætoceros concavicornis* Mangin, 16μ across (G. E. W.).

American), Skaggerak, Baltic, Gulf of Finland. Rarely in English Channel and Belgian coast.

Mangin (1917, 1919) has shown clearly that the true

C. criophilus of Castracane is an Antarctic species which does not occur in our area, and he has given the northern species the name of *Chætoceros convexicornis*.

Form *currens* (Cleve) Mangin. Cells usually single, but sometimes in chains, with the upper bristles sticking out and much wider apart than in the type (= f. *volans* Gran), but Mangin thinks it is not that of Schütt. Schütt's (1895) figure and description is very vague and it is impossible to determine his form exactly.

Chætoceros danicus Cleve, 1883.

(Fig. 89.)

Gran, Nordisches Plankton, p. 70.

Cells single or in short chains, which cling together almost without apertures. Breadth 8–20μ. Both valves

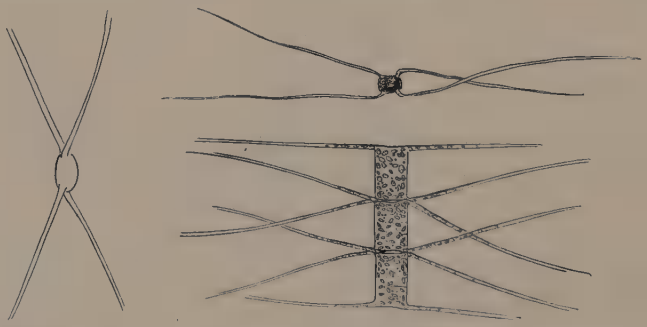


Fig. 89.—*Chætoceros danicus* Cleve, 13μ across, Plymouth (G. E. W.).

alike. Bristles armed at the thin outer part with small spines, very long, arising from near the valve margin, perpendicular to the cell axis. The bristles of one valve are situated in between those of the other, so that the four bristles form a cross in valve view. Valve surface flat, valve mantle high (almost half the height of the cell), near the margin narrowed, at the margin widening again. Neritic. Likes low salinity. Widely distributed. North temperate species.

Distribution.—Northern European and American coasts of the Atlantic, all parts of the North Sea, Finland, Danish Seas, Baltic, Skaggerak, English Channel, Belgian coast, Mediterranean.

Chætoceros tetrastichon Cleve, 1897*a*.

(Fig. 90.)

Gran, Nordisches Plankton, p. 69.

Chains as in *C. densus*, not twisted, but shorter and stronger, usually three cells with twelve similar bristles, about 10μ broad. Bristles springing from the margin of the valve, curved outwards and equally developed

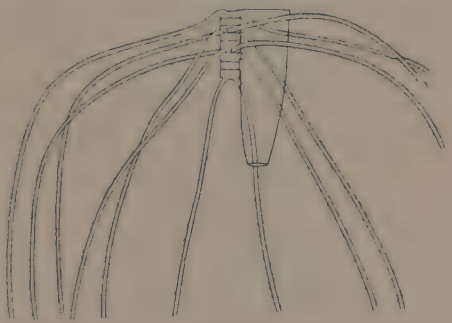


Fig. 90.—*Chætoceros tetrastichon* Cleve. After Pavillard, 1913.

with few spicules. Apertures very small or lacking. Oceanic. Tropical and temperate species.

Distribution.—Tropical and temperate Atlantic, Indian Ocean, Mediterranean; northerly limit 46° North latitude.

Famintzin (1889) described symbiosis between this species and the infusorian *Tintinnus inquilinus* O. F. Müller. Pavillard (1913) split off *C. Dadayi*, which was described by Daday (1887) as *C. tetrastichon*. Both are associated with tintinnids, but Daday's form apparently does not occur in our area. It differs from *C. tetrastichon* in having six of the bristles differing completely in direction from the others.

Sub-genus **HYALOCHÆTE** Gran, 1897*a*.

Bristles thin, without chromatophores in them. Chiefly a neritic group. Resting spores known in most species. Often when there are two maxima, in spring and summer, the resting spores are formed in spring, but not in autumn.

Section I. Oceanica.

Chætoceros decipiens Cleve, 1873*a*.

(Fig. 91.)

Gran, Nordisches Plankton, pp. 74, 75.

Chains straight, stiff, more or less flattened, usually many-celled, 12–78μ broad. Cells in broad girdle view

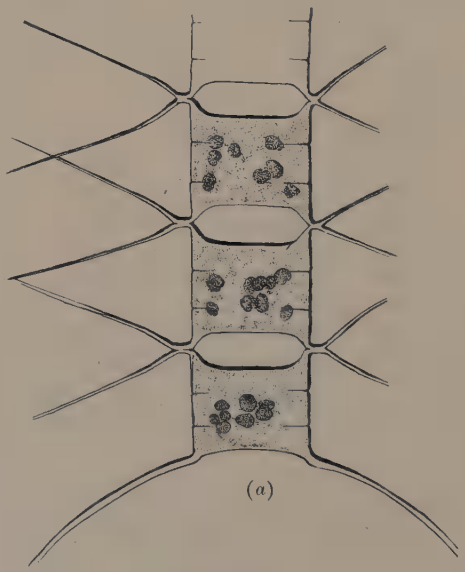
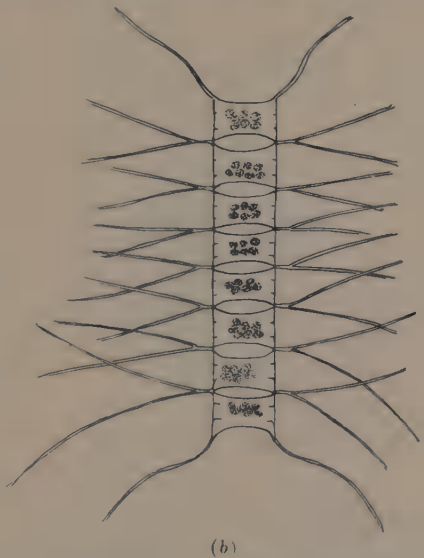


Fig. 91.

oblong with more or less produced corners, which touch those of the next cell. Apertures of various sizes, in winter usually small, linear to lancet-shaped, in summer and autumn bigger, elliptical or circular. Bristles

without special sculpture. Sometimes dotted near the extremities, arising directly from the edge of the valve and continuing perpendicular to the chain axis for a space fused together in pairs, the fused portion being two or three times as long as the diameter of the bristles. Terminal bristles shorter and thicker than the others, first directed obliquely outwards, then bent, so that the outer half is about parallel to the chain axis.



(*b*)

Fig. 91.—*Chætoceros decipiens* Cleve. (*a*) 27μ across, Plymouth (G. E. W.); (*b*) 25μ across, Plymouth (M. V. L.).

Chromatophores 4–10 in each cell. No resting spores known. Microspores seen in the first stage of formation by Gran (1904), Schiller (1909), and Ostenfeld (1910). Maximum usually in spring, and again in late summer or early autumn. Oceanic. Arctic and boreal species; likes cold water.

Distribution.—Arctic Seas, Davis Strait, Norwegian Sea, all parts of North Sea, North Atlantic (European and American), Baltic, Skaggerak, English Channel, Belgian coast, Mediterranean, California.

Section II. Dicladia.

Chætoceros mitra (Bailey), 1856.

(Fig. 92.)

Gran, Nordisches Plankton, pp. 75–76.

Apertures small, a little constricted in the middle. Bristles only fused at the point of exit, without special sculpture. Terminal bristles diverging in transapical

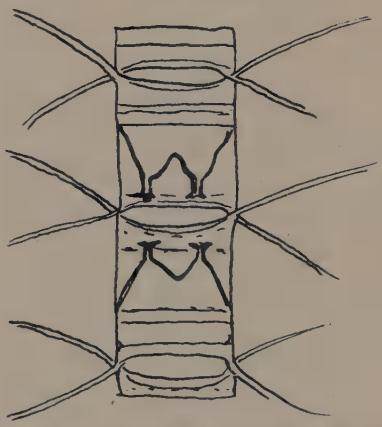


Fig. 92.—*Chætoceros mitra* (Bailey), with resting spores. After Meunier, 1915.

view, in apical view parallel and converging. Resting spores very characteristic with unlike valves. Primary valve with two high pointed processes, each bearing at the tip a solid dichotomously branched spine. Secondary valve nearly flat. Otherwise as in *C. decipiens*. Neritic.

Distribution.—Northern Polar seas, North Sea, Finland, English Channel, Belgian coast, North Atlantic (European and American).

Chætoceros Lorenzianus Grun, 1863.

(Fig. 93.)

Gran, Nordisches Plankton, p. 76.

Apertures polygonal to elliptical. Bristles only fused at their point of exit from the margin, strongly punctate,

especially the terminal bristles, which diverge for their whole length. Diameter 20–50μ. Resting spores like those of *C. mitra*, but with longer and more curved

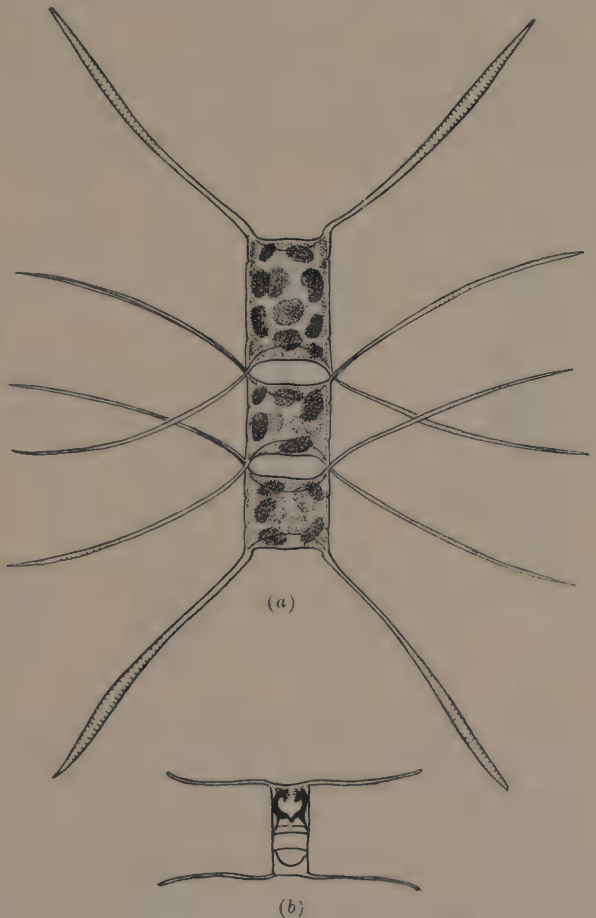


Fig. 93.—*Chætoceros Lorenzianus* Grun. (*a*) 23*u* across, Plymouth (G. E. W.); (*b*) resting spore. After Meunier, 1915.

processes on the upper valve. Neritic. Tropical and temperate coasts.

Distribution.—English Channel, Belgian coast, American North Atlantic coasts.

Section III. Cylindrica.

Chætoceros teres Cleve, 1896*b*.

(Fig. 94.)

Gran, Nordisches Plankton, pp. 76–77.

Chains straight, cylindrical, 18–48μ broad. Cells in broad girdle view oblong, with sharp corners, usually longer than broad. Apertures very narrow or almost

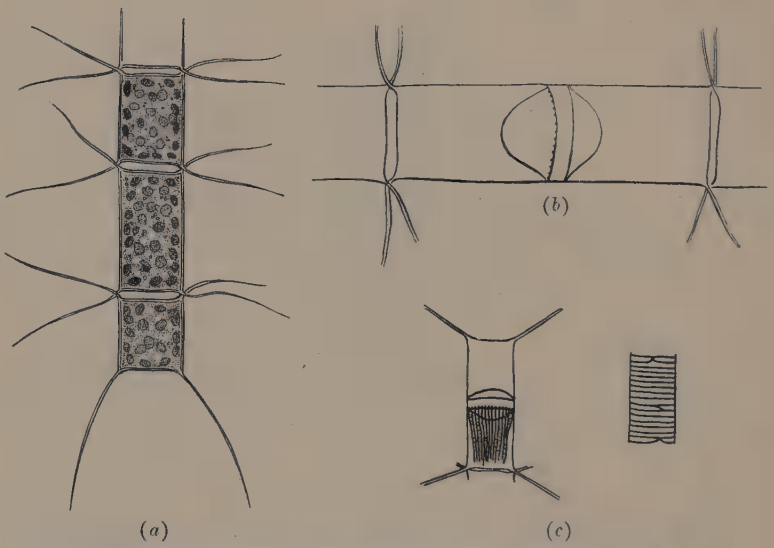


Fig. 94.—*Chætoceros teres* Cleve. (*a*) 20μ across, Plymouth (G. E. W.) (*b*) with resting spore, Norway, 25μ across (G. E. W.); (*c*) showing filaments from spore and intercalary bands. After Mangin, 1908.

absent. Valve mantle low, girdle zone very high; no constriction between mantle and girdle band. Bristles springing from the corners of the cells, without differentiated basal part, perpendicular to the chain axis, issuing obliquely on both sides of the apical plane. Chromatophores numerous. Resting spores in the middle of very much elongated cells, smooth, very fine puncta on the margin of the primary valve from which issue fine fibrils. Mangin (1908) has found numerous

intercalary bands, only visible by special methods of treatment. Neritic. Sometimes regarded as oceanic, as it often drifts far out into the open sea. Northerly-temperate or boreal form.

Distribution.—Arctic Seas, Davis Strait, Norwegian Sea, all parts of the North Sea, Baltic, Skaggerak, North Atlantic (European and American), English Channel, Belgian coast, California.

Chætoceros Lauderi Ralfs, in Lauder, 1864; Gran, 1915.

(= *C. Weissflogii* Schütt, Gran, Nordisches Plankton, pp. 77–78.)

(Fig. 95.)

Rather stronger than *C. teres* and with somewhat twisted chains, otherwise only differs in its resting spore, whose primary valve is strongly curved, narrowed

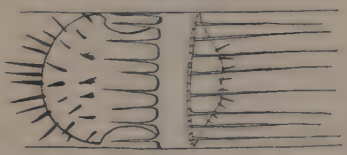


Fig. 95.—*Chætoceros Lauderi* Ralfs, resting spore, 19μ across, Kattegat (G. E. W.).

for a space between the apex and cylindrical part, on the outside of the upper part armed with spines and at the margin armed with a circle of parallel needles, directed upwards. Lower valve flatter. The spores vary much and may not be narrowed at all in the middle (Meunier, 1915). Neritic. Southerly-temperate form.

Distribution.—Southern part of North Sea, Skaggerak, Baltic, English Channel, Belgian coast.

Without the spores very like *C. teres*, but a summer form instead of spring and autumn.

Section IV. Compressa.

Chætoceros compressus Lauder, 1864; Gran, 1915.

(= *C. contortus* Schütt, 1895, Gran, Nordisches Plankton, pp. 78–79.)

(Fig. 96.)

Valves slightly convex, or flat, the bristles springing from inside the margin; basal part always distinct, outer part at first parallel to the chain axis, further out

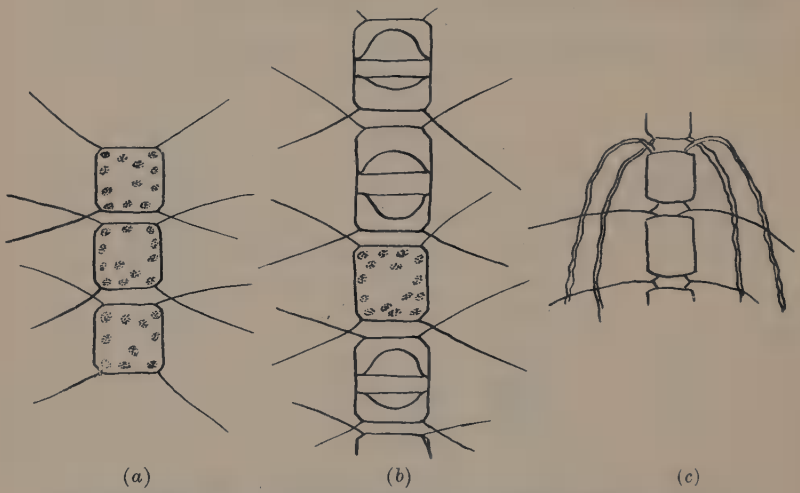


Fig. 96.—*Chætoceros compressus* Lauder. (*a*) Ordinary cells; (*b*) resting spores, 22μ across, Rhos-on-Sea (M. V. L.); (*c*) showing curved bristles. After Schütt.

bent outwards. Cells *ca.* 22μ across. Transverse section nearly or quite circular. Most of the bristles very thin, but here and there between the cells all four may be thick, short, a little spirally swollen and bent towards the same end of the chain. Mangin (1912) did not find these thick, curved bristles in his Atlantic specimens, and they were not seen in those from the Welsh coast examined by the writer. Chromatophores small, 4–20 in each cell. Resting spores in the middle of the mother-cell (as in the French and Welsh specimens) or

at one end (Gran), with a thick girdle band fused to it, smooth, with one row of small spines on the upper margin in the primary valve according to Gran, not shown by Meunier nor Mangin, and not present in the Welsh specimens. Neritic. Boreal to southerly-temperate species. Very important in Danish seas.

Distribution.—Arctic seas, Davis Strait, Norwegian Sea, all parts of the North Sea, Baltic, Skaggerak, North Atlantic (European and American), English Channel, Belgian coast, Mediterranean, California, Indian Ocean.

Meunier (1910) in his Arctic material found auxospores coming from the sides of the cells, which formed new cells at right angles to the mother-cell.

Section V. Protuberantia.

Chætoceros didymus Ehr., 1845.

(Fig. 97.)

Gran, Nordisches Plankton, pp. 77–80.

Chains straight, breadth 11–36μ. Cells compressed in broad girdle view, with convex end surfaces with a semicircular knob in the middle of the valve. Bristles springing from the corners of the cells, crossing one another at their base or further out, sometimes rather far outside the chains (v. *anglica*). Chromatophores two in each cell, pressed against the valves, each with a pyrenoid that has its position in the central knob. Resting spores in pairs together, with short thick horns and smooth valves, formed inside specially formed mother-cells without the central knob. By means of these horns they can float for a long time. Neritic. Likes fairly warm water. Southerly-temperate species.

Distribution.—Norwegian and Danish seas, all parts of the North Sea, Baltic, Skaggerak, Cattegat, English Channel, Belgian coast, North Atlantic (European and American), Mediterranean, California.

In the type the rather strong bristles cross one another almost at the base. In v. *anglica* the fine bristles cross outside the chain.

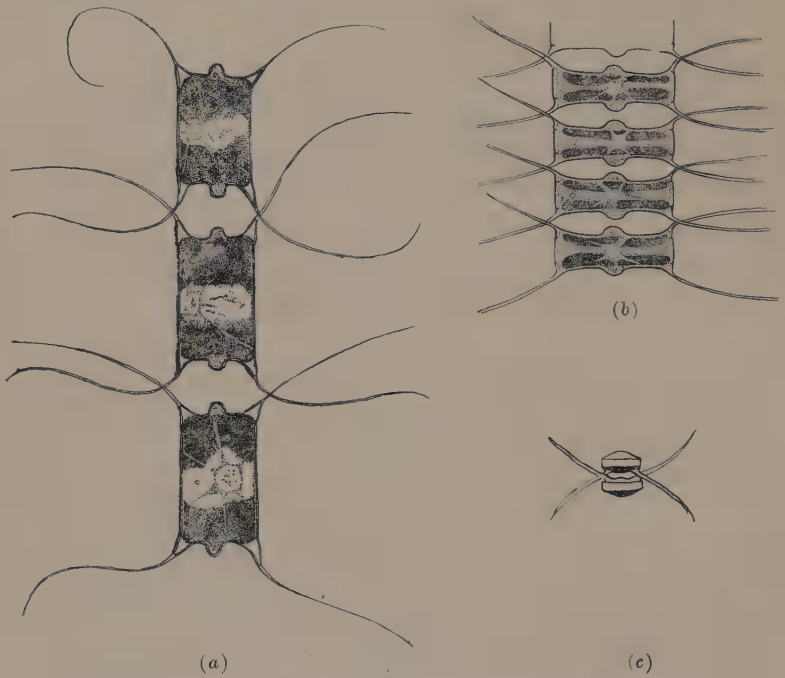


Fig. 97.—*Chætoceros didymus* Ehr. (*a*) 20μ across; (*b*) 33μ across, Plymouth (G. E. W.); (*c*) resting spores. After Meunier.

Section VI. Constricta.

Chætoceros constrictus Gran, 1897*a*.

(Figs. 98, 5*e*.)

Gran, Nordisches Plankton, p. 80.

Chains straight, 14–35μ broad. Cells in broad girdle view oblong, with sharp corners. Between the valves and girdle band is a distinctly marked constriction. Valve surface concave, apertures symmetrically lanceform, slightly narrowing in centre. Chromatophores

two in each cell, pressed against both valves. Bristles without basal part, the outer part bent at first at right angles to the chain axis. Terminal bristles distinctly marked, diverging at an acute angle. Resting spores in the middle of the mother-cell, beset on both valves with short spines. Gran (1915) has described auxospores which come from the centre of the cell at right angles as in *C. Eibenii* enclosing resting spores. Neritic. Northerly-temperate form.

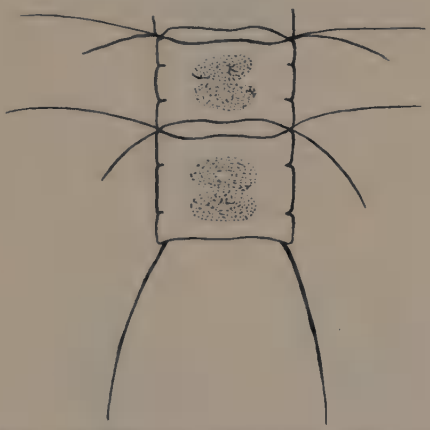


FIG. 98.—*Chætoceros constrictus* Gran, 25μ across, Rhos-on-Sea (M. V. L.).

Distribution.—All parts of the North Sea, Skaggerak, Norwegian and Danish seas, Baltic, North Atlantic (European and American), English Channel, Belgian coast, California. Maximum in spring, sometimes in autumn.

Section VII. STENOCINCTA.

Chætoceros affinis Lauder, 1864; Gran, 1915.

(= *C. Schüttii* Cleve, Gran, Nordisches Plankton, p. 81.)

(Fig. 99.)

Several species come under this head. Pavillard (1925) gives *C. Ralfsii* Cleve, *C. Schüttii* Cleve, *C. javanicus* Cleve, *C. distinctus* Schütt, *C. angulatus* Schütt,

C. procerus Schütt, *C. najadianus* Schüssnig, *C. adriaticus* Schüssnig and *C. Willei* Gran. Gran himself regards *C. affinis* as a central type of a group of forms all

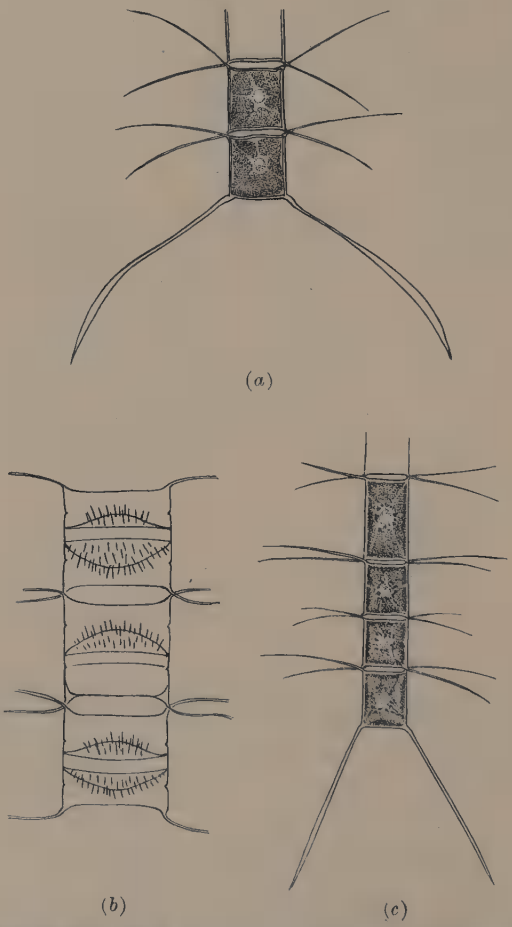


FIG. 99.—*Chætoceros affinis* Lauder. (*a*) 20μ across, Plymouth; (*b*) 20μ across, Norway, showing resting spores; (*c*) var. *Willei* Gran, 15μ across, Plymouth (G. E. W.).

belonging to the same species, having in common the uniformity of the resting spores and the constant presence of a minute knob at the centre of the terminal valves.

Chain straight, 9–22μ broad. Cells in broad girdle view oblong with sharp corners which touch those of the neighbouring cell. Apertures lancet-form, in the middle slightly constricted. Girdle zone usually very narrow. Terminal bristles strongly divergent, thick. Chromatophores one in each cell, lying against the broad side of the girdle. Resting spores in the middle of the mother-cell, on both sides beset with small spines. The rounded primary valve bears small spines over its whole surface; the secondary valve is almost flat with a knob in the middle, and bears only in the middle a number of long spines. Likes fairly warm water. Neritic. Southerly-temperate species.

Distribution.—All parts of the North Sea, Danish seas, Skaggerak, Finland, North Atlantic, English Channel, Belgian coast, Mediterranean, California.

Chætoceros Willei Gran (Nordisches Plankton, p. 81), is, according to Ostenfeld, a boreal and more oceanic form of this species. This view is accepted by Cleve, Meunier and Pavillard. It is slenderer, frailer, more weakly silicified, aperture very narrow, sometimes almost absent, terminal bristles only diverging at an acute angle, thin. It is recorded from the Gulf of Maine and Woods Hole, as well as from our seas.

Section VIII. Laciniosa.

Chætoceros laciniosus Schütt, 1895 (including **C. pelagicus** Cleve).

(Fig. 100.)

Gran, Nordisches Plankton, p. 82.

Chains straight, 7–42μ broad. Cells in broad girdle view rectangular, with slightly projecting corners rounded at the outside. Valve surfaces in the middle slightly swollen, but without the characteristic knobs of *C. didymus*. Apertures large and broad, oblong with rounded corners, in the middle slightly constricted. Bristles thin, their basal part parallel with the chain

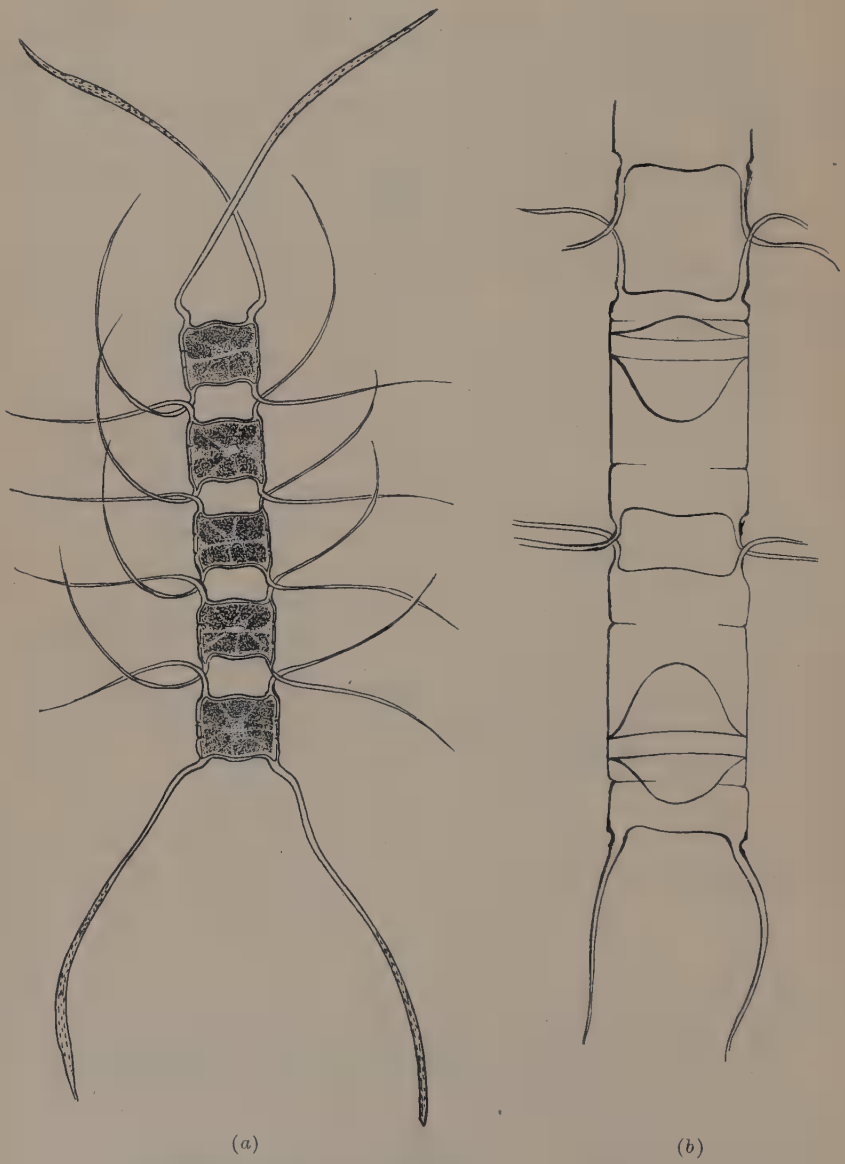


FIG. 100.—*Chætoceros laciniosus* Schütt. (*a*) 25μ across, Plymouth; (*b*) 15μ across, Kattegat, with resting spores (G. E. W.).

axis, the outer part further out usually bent towards one end of the chain. Terminal bristles thick, distinctly different from the others, in broad girdle view almost parallel, in narrow girdle view more diverging, armed with small spines. Chromatophores two in each cell, attached to both valves, each with a central pyrenoid. Resting spores smooth, not in the middle of the mother-cell but lying rather near the younger valve. Neritic. Temperate form. Maximum in spring and autumn.

Distribution.—Arctic Seas, Davis Strait, Norwegian Sea, Baltic, all parts of the North Sea, North Atlantic (European and American), English Channel, Belgian coast, Mediterranean, California.

Gran (1915) includes Cleve's *C. pelagicus* in this species.

Chætoceros brevis Schütt, 1895.

(Fig. 101.)

Gran, Nordisches Plankton, p. 83.

Nearly related to *C. laciniosus*, but differs in having only one chromatophore in each cell, which is pressed against one valve, and bristles almost straight, not so far from the apical plane. Terminal bristles diverging in broad girdle view at an angle of about 90° or more. Resting spores lower than in *C. laciniosus* with fine spicules on the valve. Maximum in spring with resting spores following. Another in autumn without resting spores. Neritic. Temperate species.

Distribution.—All parts of the North Sea, Skaggerak, Baltic, English Channel, North Atlantic (European and American), California, Indian Ocean.

Section IX. Diadema.

Chætoceros diadema (Ehr.), 1854.

(Fig. 102.)

Gran, Nordisches Plankton, p. 84.

Chains straight, 11–46μ broad. Cells in girdle view rectangular with weakly rounded corners. Valves

slightly convex, apertures long, oval, gradually narrowing towards the middle. Bristles springing from the

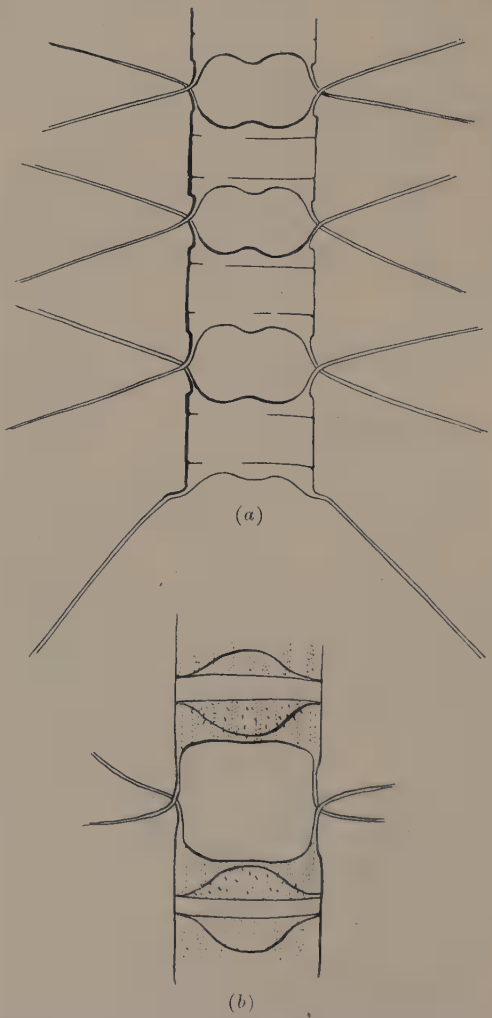


FIG. 101.—*Chætoceros brevis* Schütt. (*a*) 21μ across, Plymouth; (*b*) 20μ across, Kattegat, with resting spores (G. E. W.).

corners of the cells, directed transversely to chain axis. Terminal bristles diverging at an acute angle.

Chromatophores one in each cell, attached to the broad side of the girdle. Resting spores somewhat nearer one valve of the mother-cell, the older valve with 4–12 straight, dichotomously branched spines, the younger smooth. Neritic. Boreal-arctic form. Maximum in spring. A Northern neritic species of wide distribution.

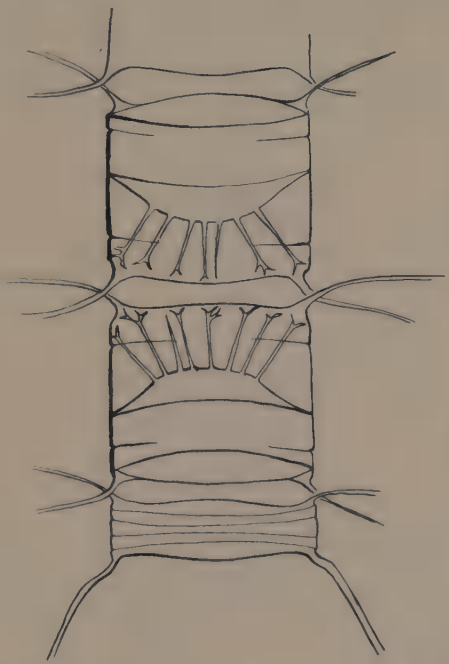


FIG. 102.—*Chætoceros diadema* (Ehr.), 40μ across, Kattegat, with resting spores (G. E. W.).

Distribution.—Arctic seas, Davis Strait, E. Greenland Sea, Finland, all parts of the North Sea, Skaggerak, Baltic, English Channel, I. of Man, Belgian coast, Bay of Biscay, Mediterranean, N. Atlantic and Pacific coasts of America.

Busch (1916) describes large armed bristles in winter among the ordinary kind, from Kiel.

Chætoceros coronatus Gran, 1897*a*.

(Fig. 103.)

Gran, Nordisches Plankton, p. 85.

Chains straight, 14–19μ broad. Cells in broad girdle view oblong, with sharp corners. Apertures lancet-shaped. Chromatophores one in each cell, attached to the broad side of the girdle. Resting spores in the middle of the mother-cell, their primary valves with a row of parallel, not quite straight marginal spines which may branch, otherwise smooth. Neritic. With-

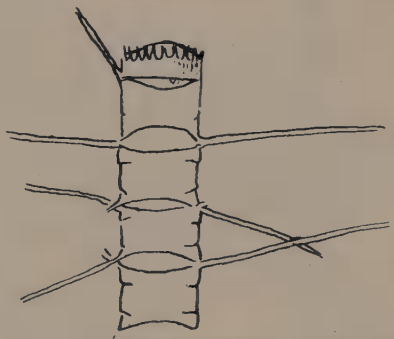


Fig. 103.—*Chætoceros coronatus* Gran. After Gran, 1897*a*.

out the resting spores this species is very like *C. seiracanthus*.

Distribution.—Southern North Sea, Danish seas, Belgian coast.

Chætoceros holsaticus Schütt, 1895.

(= *C. balthicus* Cleve.) Gran, Nordisches Plankton, pp. 85–86.

(Fig. 104.)

Chains straight, very brittle, 6–24μ broad, cell wall thin and weakly siliceous. Cells in broad girdle view oblong, with flat valves. Bristles short, springing from the inside of the valve margin. Apertures oblong, at least half as large as the cells. Chromatophores one

in each cell, attached to the broad side of the girdle. Resting spores in the middle of the mother-cell, beset on both sides with small spines. The primary valve distinctly bigger than that of the secondary valve,

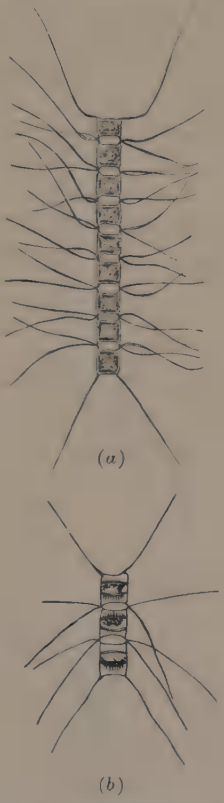


FIG. 104.—(*a*) *Chætoceros holsaticus* Schütt, 10μ across, Plymouth (G. E. W.); (*b*) with resting spores. After Gran, 1905.

which can be almost smooth. Neritic. Occurs with ice. Cold water and brackish form; proper habitat in Baltic.

Distribution.—Baltic, Skaggerak, N. Norway, Gulf of Finland, Gulf of Bothnia, North Atlantic, Belgian coast, English Channel.

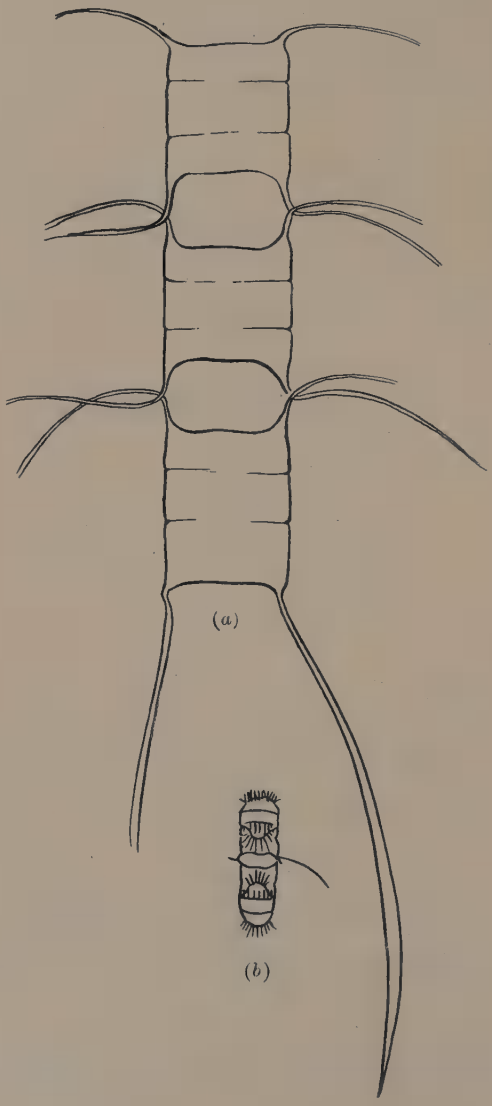


Fig. 105.—(*a*) *Chætoceros seiracanthus* Gran, 13μ across, Kattegat (G. E. W.); (*b*) resting spores. After Gran, 1897*a*.

Chætoceros seiracanthus Gran, 1897*a*.

(Fig. 105.)

Gran, Nordisches Plankton, p. 85.

Chains straight, 12–24μ broad, closely related to *C. diadema*, but slighter in build with larger apertures and differs in the resting spores, which are in both valves beset with thin unbranched spines, and bear on the outside of the margin of the primary valve a crown of thin parallel needles. Neritic.

Distribution.—Danish seas, Finland, North Sea, North Atlantic (European and Atlantic), English Channel, Belgian coast.

Chætoceros difficilis Cleve, 1900*a*.

(Fig. 106.)

Gran, Nordisches Plankton, p. 86.

Chains straight, but loose and pliable, 8–10μ broad, cell-wall weakly siliceous. Cell in broad girdle view

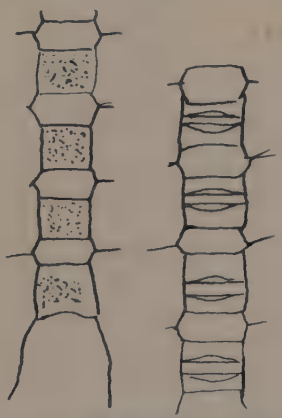


Fig. 106.—*Chætoceros difficilis* Cleve. After Cleve, 1900*a*.

rectangular, apertures oblong, half as big as the cell. Bristles very thin. One chromatophore in each cell, attached to the broad side of the girdle. Resting spores

in the middle of the cell, flat, smooth. Hardly distinguishable from *C. holsaticus* except by the resting spores, which are like those of *C. compressus*, that species, however, having numerous chromatophores. Neritic.

Distribution.—English Channel, North Sea, Gulf of Maine, California.

Section X. Diversa.

Chætoceros furca Cleve, 1897*a*.

(Fig. 107.)

Gran, Nordisches Plankton, p. 87.

Chains straight, 12–14μ broad. Cell rectangular with conspicuous corners by which the neighbouring cells

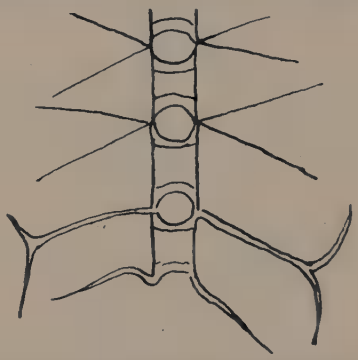


Fig. 107.—*Chætoceros furca* Cleve. After Cleve, 1897*a*.

touch one another. One chromatophore, placed near the girdle. Bristles thin. End bristles strongly diverging, unlike one another, one directed backwards from the chain. In most of the chains the bristle pairs are similar to their neighbours, whilst some are fused for two-thirds of their length, so that the basal part is only a single bristle, which forks at its second third. These forked horns are thicker than the others, and armed with spirals of conspicuous small spines. Oceanic.

Distribution.—Tropical and sub-tropical seas, Mediterranean, California. Northerly limit 49° north lattiude.

Chætoceros diversus Cleve, 1873*a*.

(Fig. 108.)

Gran, Nordisches Plankton, p. 87.

Cells in broad girdle view oblong, the neighbouring cells touching one another at the corners or also by the middle part, so that the apertures are absent or almost completely so. One chromatophore, attached to the girdle. Bristles various, partly hair-like, partly

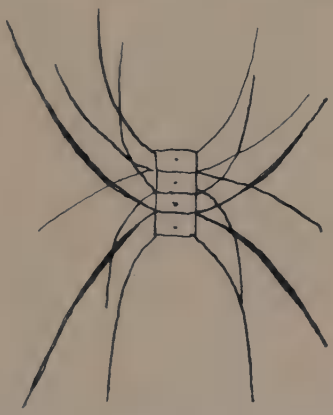


Fig. 108.—*Chætoceros diversus* Cleve. After Cleve, 1897*a*.

thickened from within outwards, the outer thick part angular and covered with fine spines. Terminal bristles hair-like. Neritic.

Distribution.—North Sea.

Section XI. Brevicatenata.

Chætoceros similis Cleve, 1896*b*.

(Fig. 109.)

Gran, Nordisches Plankton, pp. 87–88.

Chains of few cells, straight, 7–17μ broad. Cells in broad girdle view oblong with somewhat knobbed valves, which touch one another in the middle, but not

at the sides. Bristles springing from the corners directly apicalwards, crossing point somewhat outside the chain. Terminal bristles rather thicker than the others, strongly diverging, about parallel with the other bristles. Apertures narrow, divided by the knob into two parts. Two chromatophores. Resting spores pear-shaped, in the middle of the mother-cell, armed on both

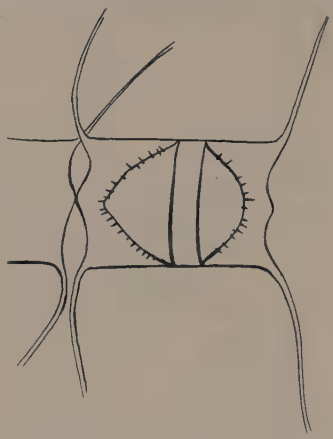


Fig. 109.—*Chætoceros similis* Cleve, 13μ across, Kattegat, with resting spore (G. E. W.).

valves with small spicules. Cold water form. Neritic. Northerly temperate species.

Distribution.—All parts of the North Sea, Norwegian Sea, Skaggerak, Baltic, Belgian coast, North Atlantic.

Chætoceros subtilis Cleve, 1896*b*.

(Fig. 110.)

Gran, Nordisches Plankton, p. 88.

Chains of few cells, straight, 5–15μ broad. Cells in broad girdle view oblong. Apertures quite narrow or absent. Bristles springing from the corners, crossing one another directly at the base, thin, all bent towards the hind end of the chain. Terminal bristles at the front not different from the others, longer and thicker

at the hind end, only diverging slightly. One chromatophore. Resting spores in the middle of an elongated cell, armed on both valves with small spines. Neritic. Likes a low salinity and cold water.

Distribution.—Baltic, Kattegat, Finland. Rare on Belgian coast. North Atlantic, American coast.

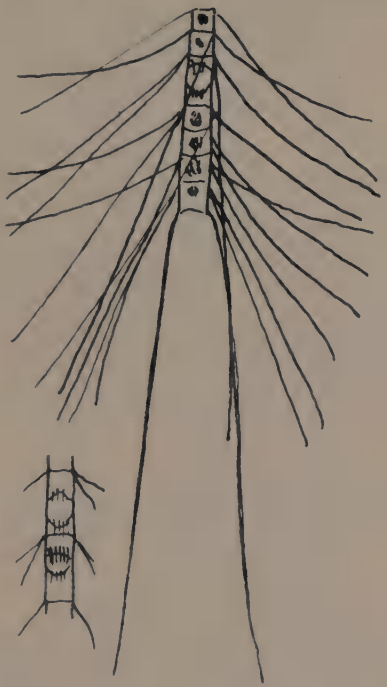


FIG. 110.—*Chætoceros subtilis* Cleve. After Ostenfeld, 1901*a*.

Chætoceros Wighami Brightw., 1856.
(Fig. 111.)

Gran, Nordisches Plankton, pp. 88–89.

Chains straight, of few cells, 7–15μ broad. Cells in broad girdle view oblong with sharp corners, by which the neighbouring cells touch; rather concave valves. Apertures linear to a broad lancet-form. One chromatophore. Bristles thin, some about parallel to the chain

axis, others standing straight out. Terminal bristles not thicker than the others, curved more or less in an S. Resting spores in the middle of the mother-cell, armed on both valves, or only on the primary valve,

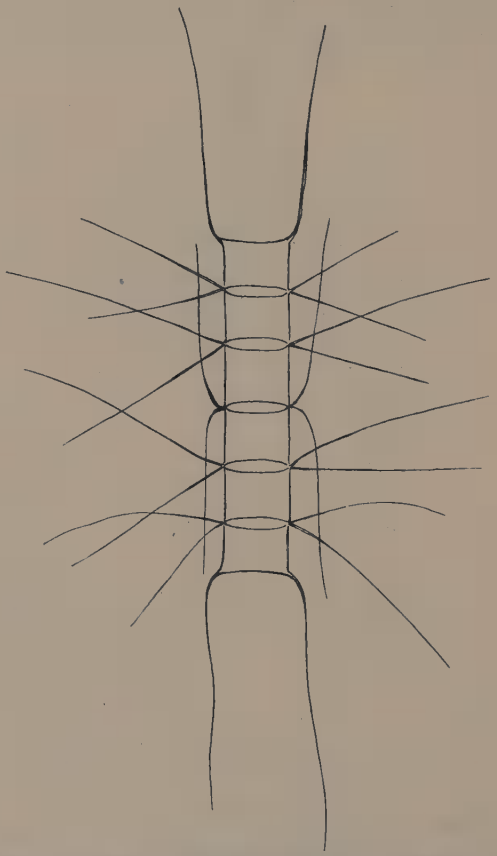


Fig. 111.—*Chætoceros Wighami* Brightw., 13μ across, Kattegat (G. E. W.).

with small spines. Neritic. Often occurring with *C. holsaticus*. Baltic form. Maximum in spring.

Distribution.—Davis Strait, Danish seas, Skaggerak, Baltic, English Channel, rare on Belgian coast, Mediterranean, North Atlantic coast of America.

Chætoceros perpusillus Cleve, 1897*a*.

(Fig. 112.)

Gran, Nordisches Plankton, p. 89.

Chains straight, short, consisting of 3–7 cells, 4–5μ broad. Cells in broad girdle view oblong; apertures narrow, slit-like. Incompletely known. Neritic.

Distribution.—Northern Atlantic.

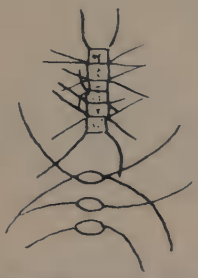


FIG. 112.—*Chætoceros perpusillus* Cleve. After Cleve, 1897*a*.

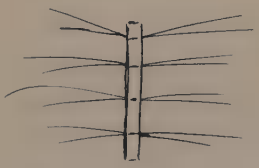


FIG. 113.—*Chætoceros filiformis* Meunier. After Meunier, 1910.

Chætoceros filiformis Meunier, 1910.

(Fig. 113.)

Meunier, 1910, p. 252.

Straight, narrow chains, no visible apertures, with thin short bristles scarcely visible, 3μ across. Rather like *C. perpusillus*. (Meunier). Neritic.

Distribution.—Arctic seas.

Chætoceros exospermus Meunier, 1915.

(Fig. 114.)

Meunier, 1915, p. 48.

Small cells, isolated or in chains of 2 or 3, touching by their valves at the corners, leaving lozenge-shaped

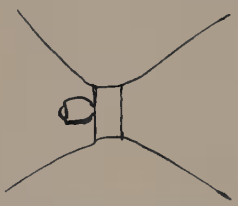


FIG. 114.—*Chætoceros exospermus* Meunier. After Meunier, 1915.

apertures. Fine bristles, fused at their origin, diverging much and facing outwards, so that those of each valve face opposite ways (Meunier). Resting spores formed outside at right angles in rounded masses, not thicker than the mother-cells. Brackish water form.

Distribution.—Belgian coast.

Chætoceros karianus Grun. (Cleve and Grunow, 1880). (Fig. 115.)

Meunier, 1910, p. 246.

Short straight chains with terminal bristles, different in strength and curvature from the others. Apertures lenticular in old specimens, very narrow slits in the

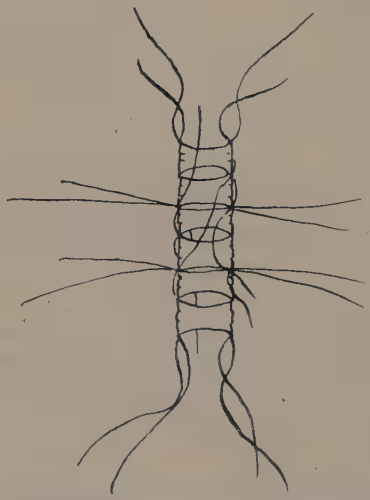


FIG. 115.—*Chætoceros karianus* Grun. After Meunier, 1910.

others. Bristles fused at their origin from the corners of the valves, the older bristles curving in rather more than a semicircle and then back. Newer bristles much straighter. 15μ across.

Distribution.—The glacial ocean North of Barents Sea.

Chætoceros fragilis Meunier, 1910.

(Fig. 116.)

Meunier, 1910, p. 244.

Small, delicate, in fragile chains. Cells rectangular in girdle view. Slightly rounded angles. Short thin bristles, flexible, fused after crossing, so that the sides of the apertures are formed by their bases. About 8μ across (Meunier).

Distribution.—Arctic seas.

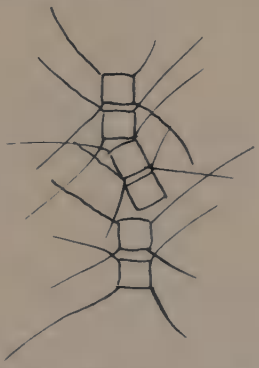


Fig. 116.—*Chætoceros fragilis* Meunier. After Meunier, 1910.

Chætoceros crinitus Schütt, 1895.

(Fig. 117.)

Gran, Nordisches Plankton, p. 89.

Chains straight, 15–25μ broad; apertures very narrow, a little contracted in the middle. Cells in broad girdle view oblong, with rounded corners. One large chromatophore. Bristles long and thin, springing from a little way within the valve margin, basal part very short and rudimentary. Terminal bristles shorter, but not thicker than the others, at first bent out, then again bent in, and finally about parallel with the chain axis. Resting spores in the middle of the mother-cell or somewhat to one side, with rounded primary valve with small

spines, and smoother secondary valve. Northerly temperate neritic species.

Distribution.—Southern part of North Sea, Skaggerak, Danish Seas, English Channel, Belgian coast. Usually in summer.

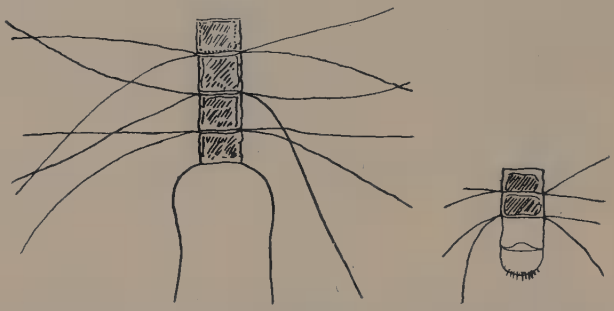


FIG. 117.—*Chætoceros crinitus* Schütt. After Ostenfeld, 1901*a*.

Chætoceros pseudocrinitus Ostenfeld, 1901*a*.

(Fig. 118.)

Gran, Nordisches Plankton, p. 90.

Chains straight, 8–29μ broad. Cells in broad girdle view rectangular, with sharp corners, with a distinct constriction between the valves and girdle zone. Apertures slit-like. One chromatophore, two when cell is about to divide. Thin bristles arising from the corners of the valves, crossing at the point of exit. Terminal bristles not appreciably thicker or shorter than the others, bent out so as to be far removed from the chain, then about parallel with the chain axis. Resting spores formed in auxospores arising from the girdle portion at right angles, convex upper valve with spines, smooth nearly flat lower valve, described and figured by Gran, 1915. Similar resting spores, but with spines on lower valve also, without auxospores, inside cells, in a culture by Dr. Allen, 1928.

Distribution.—Davis Strait, southern part of North Sea, Skaggerak, Baltic, North Atlantic, English Channel, California.

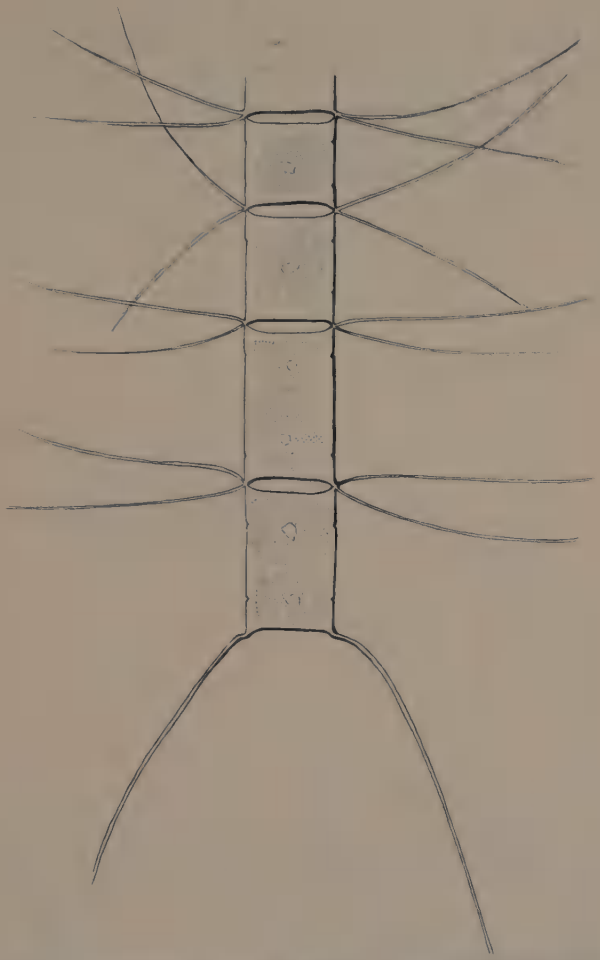


Fig. 118.—*Chætoceros pseudocrinitus* Ostenf., 11μ across, Plymouth (G. E. W.).

Chætoceros ingolfianus Ostenfeld (in Gran, 1902).
(Fig. 119.)

Gran, Nordisches Plankton, pp. 90–91.

Chains straight, 9–18μ broad. Cells in broad girdle view rectangular with sharp corners, by which the neighbouring cells are directly in contact. Apertures small, slit-like. One chromatophore. Bristles springing

from the corners of the cells, almost straight; directed towards both sides of the chain, diverging from one another at an obtuse angle; basal part rudimentary. Terminal bristles as in *C. pseudocrinitus*, at first perpendicular to the chain axis or bent back, far from the

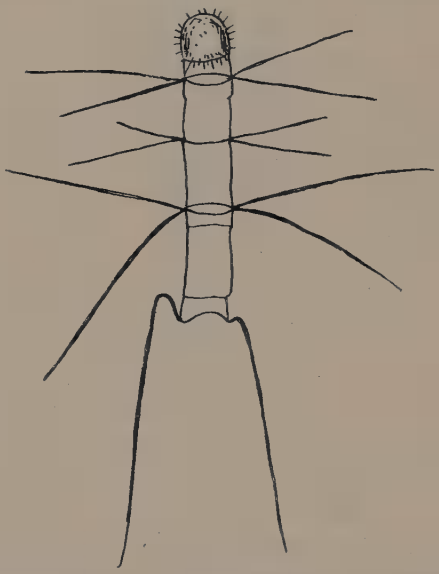


Fig. 119.—*Chætoceros ingolfianus* Ostenfeld. After Gran, 1905.

apical plane, further out parallel to the chain axis. Resting spores armed with spines, not only on the end-surface but also on the girdle zone so that the cell-wall of the mother-cell is bulged out. Closely related to *C. pseudocrinitus*. Neritic.

Distribution.—Danish seas.

Section XII. Curviseta.

Chætoceros curvisetus Cleve, 1889.

(Fig. 120.)

Gran, Nordisches Plankton, pp. 91–92.

Chains spirally curved, without distinct end-cells, 10–29μ broad. Cells in broad girdle view oblong, with

conspicuous corners, by which the neighbouring cells are connected. Apertures rhombo-elliptical to circular. One chromatophore with a large pyrenoid in the middle. Bristles arising from the corners of the cells, all bent towards the same side of the chain, *i. e.* towards the outside of the curved axis of the spiral, so that on one small piece of the chain seen in broad girdle view all bristles point towards or away from the observers. Resting spores smooth, with a row of puncta on the primary

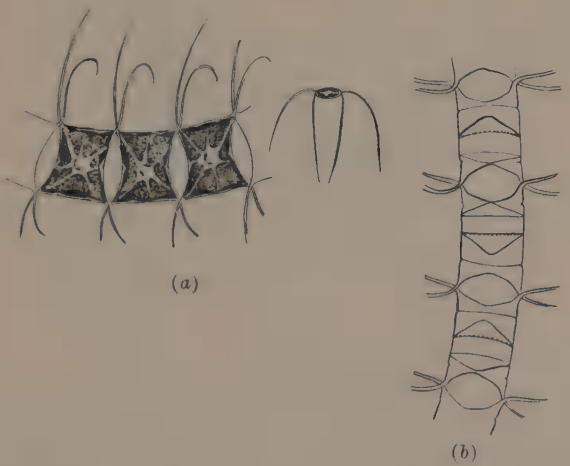


Fig. 120.—*Chætoceros curvisetus* Cleve. (*a*) 15μ across, Plymouth; (*b*) 18μ across, Kattegat, with resting spores.

valve, about in the middle of the mother-cell, surrounded by the thickened girdle of the mother-cell. Pavillard (1905) found these all the year round in the Mediterranean, but especially in October; also auxospores in February. Neritic. Southern coast form from temperate European coasts of the Atlantic northwards.

Distribution.—All parts of the North Sea, Norwegian Sea, Skaggerak, Baltic, English Channel, Belgian coast, North Atlantic (European and American), Mediterranean, California.

Chætoceros debilis Cleve, 1894.

(Fig. 121.)

Gran, Nordisches Plankton, p. 92.

Chains strongly curved, 12–29μ broad, without special end-cells. Cells in broad girdle view oblong, with rounded corners and flat or weakly convex valves,

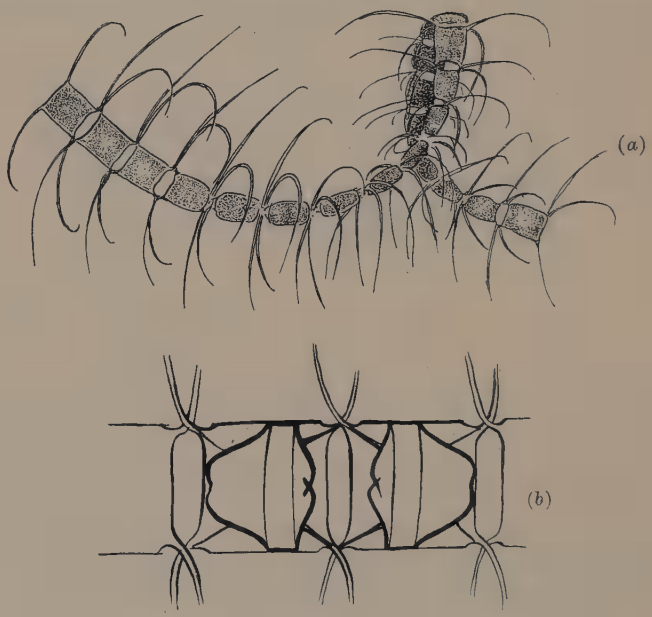
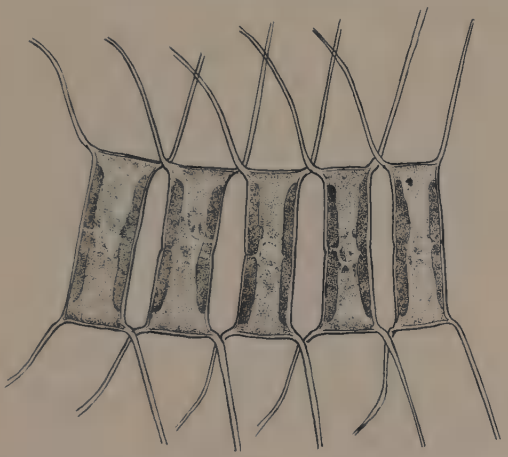


Fig. 121.

which do not touch those of the neighbouring cells. Apertures longish, with parallel sides or in the middle somewhat contracted. One chromatophore. Bristles thin, arising somewhat inside the corners, with crossing point a little outside their base, bent in the same way as in *C. curvisetus*. Resting spores in the middle of the mother-cell, both valves with two low knobs, the primary valve having two strong bristles ending in the corners of the mother-cell, the secondary valve having them less

developed or absent. Neritic. Northerly temperate form.

Distribution.—Arctic and Norwegian seas, Davis Strait, all parts of the North Sea, Skaggerak, Baltic, North Atlantic (European and American), English Channel. Commonest species on the Belgian coast. Japanese records somewhat doubtful. California.



(*c*)

FIG. 121.—*Chætoceros debilis* Cleve. (*a*) 13μ across, Plymouth; (*b*) 18μ across, Kattegat, with resting spores; (*c*) 28μ across, Plymouth (G. E. W.).

Chætoceros pseudocurvisetus Mangin, 1910.

(Fig. 122*a*.)

Mangin, 1910, p. 348.

Cells compressed. Apertures lenticular, at the insertion of the bristles slightly fused. Four protuberances on each valve connected with similar knobs on the adjacent cells. These knobs are described by Gran and Yendo (1914) from Japanese specimens. Valve face rectangular with bent angles. Bristles joined at their insertion. Otherwise like *C. curvisetus*. Breadth 26μ. Neritic.

Distribution.—Coast of Brittany, Japanese Seas.

Chætoceros adhærens Mangin, 1912.

(Fig. 122*b*.)

Mangin, 1912, p. 39.

Chains of straight cells, 10μ long, 28μ broad. Valve face slightly excavated in the centre, protruding at

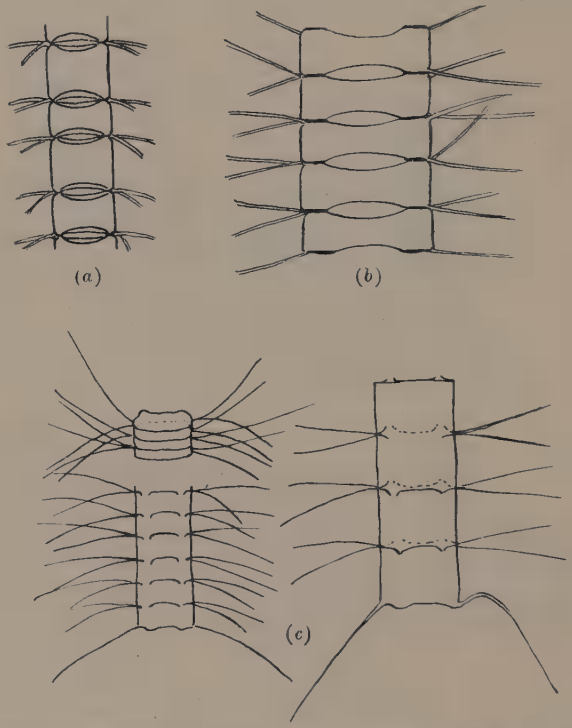


Fig. 122.—(*a*) *Chætoceros pseudocurvisetus* Mangin, after Mangin, 1910; (*b*) *Chætoceros adhærens* Mangin; (*c*) *Chætoceros imbricatus* Mangin, after Mangin, 1912.

the sides and here joined with the adjacent cell with cushions of a pectic substance. Bristles sharp, slightly diverging, inserted on the rounded angles on the inner sides of the valves. Apertures very narrow. Resting spores unknown (Mangin).

Distribution.—Atlantic, off the Brittany coast.

Chætoceros imbricatus Mangin, 1912.

(Fig. 122*c*.)

Mangin, 1912, p. 51.

Chains straight or slightly curved, ovato-rectangular in outline in girdle view; cells very much compressed, no intercellular spaces, rectangular on the contiguous faces, angularly rounded, sending out processes on the inside of the insertion of the bristle to the valvar face of the adjacent cell, which is drawn out in such a manner that the cells interlock more or less perfectly. Bristles bearing slender setæ diverging at first, afterwards curving towards the apex of the chain. Breadth 12–20μ. Resting spores unknown (Mangin).

Distribution.—Atlantic, off the Brittany coast.

Section XIII. Anastomosantia.

Chætoceros externus Gran, 1897*a*.

(Fig. 123.)

Gran, Nordisches Plankton, p. 93, as *C. anastomosans* (not *C. anastomosans* Grun.).

Chains straight or slightly curved, without special end-cells, easily broken, and on that account usually only a few cells are seen together, 10–20μ broad. Cells in broad girdle view oblong with slightly rounded corners which do not touch their neighbours. Transverse section oval or circular. Two chromatophores in each cell. Bristles very thin, with long base directed outwards from the corners of the cells, not directly connected with the corresponding bristle of the next cell, but bound to it by a cross piece, the bases of the bristles of adjoining cells exactly parallel, so that looked at in valve view they appear as one until they are joined by the cross-piece when they diverge. Resting spores in the middle of the mother-cell with spines on both valves. Neritic.

Distribution.—Southern North Sea, Belgian coast, Brittany coast (Atlantic).

Mangin (1912) has described different forms and aspects of this species from the Atlantic showing that the transverse section may be completely circular. Pavillard (1916 and 1925) has shown that this species is not the same as *C. anastomosans*, common in the Mediterranean, usually confused with it.

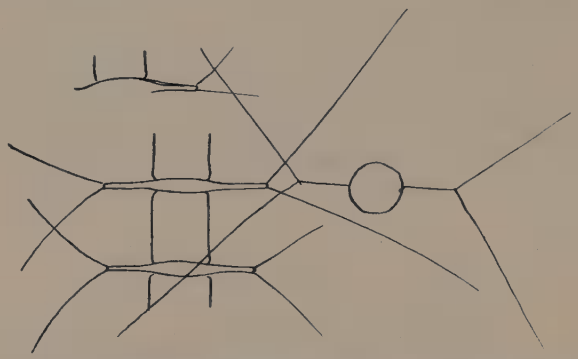


Fig. 123.—*Chætoceros externus* Gran. After Mangin, 1912.

Section XIV. Furcellata.

Chætoceros scolopendra Cleve, 1896*b*.

(Fig. 124.)

Gran, Nordisches Plankton, pp. 93–94.

Chains straight or weakly curved, strongly twisted on the chain axis, 9–25μ broad, without special end-cells. Cells in broad girdle view oblong, with slightly rounded corners, which do not touch their neighbours. Apertures rounded-rectangular, slightly compressed in the middle. Bristles arising from just inside the corners, all bent out transversely, beset with small spines, out of which issue slime-threads. One chromatophore. Resting spores in pairs close together on two sister-cells (without apertures), with peculiar smooth, thick setæ

which fuse for a space and further out again separate in order to surround the cell like a girdle. Neritic. Northerly temperate species.

Distribution.—Davis Strait (single chain), all parts of the North Sea, Norwegian Sea, Skaggerak, Kattegat, English Channel, Belgian coast, North Atlantic (European and American), California.

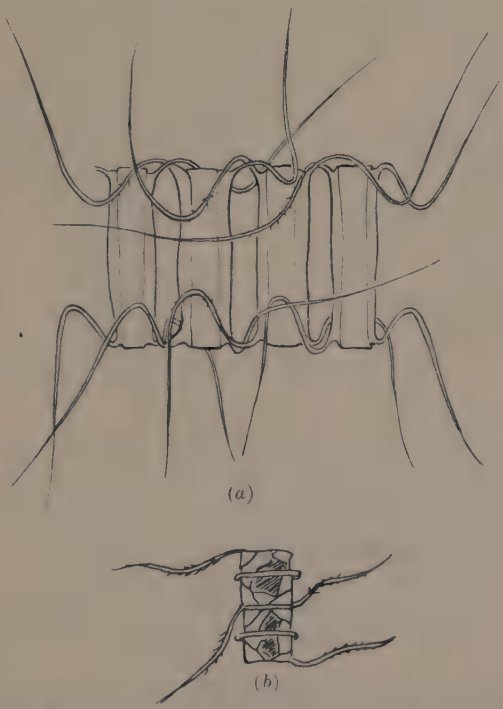


FIG. 124.—*Chætoceros scolopendra* Cleve. (*a*) 20μ across, Kattegat (G. E. W.); (*b*) with resting spores. After Ostenfeld, 1901*a*.

Chætoceros cinctus Gran, 1897*a*.

(Fig. 125.)

Gran, Nordisches Plankton, p. 94.

Chains straight or weakly curved, without special end-cells, 5–15μ broad. Differs from *C. scolopendra* in

its smaller size and by the thinner bristles, which are not so strongly bent and have no spines. Otherwise like the previous species. Neritic. Southerly temperate form. Resting spores described by Meunier (1915), like *C. scolopendra*.

Distribution.—North Sea, Norwegian Sea, Belgian coast, North Atlantic (European and American).

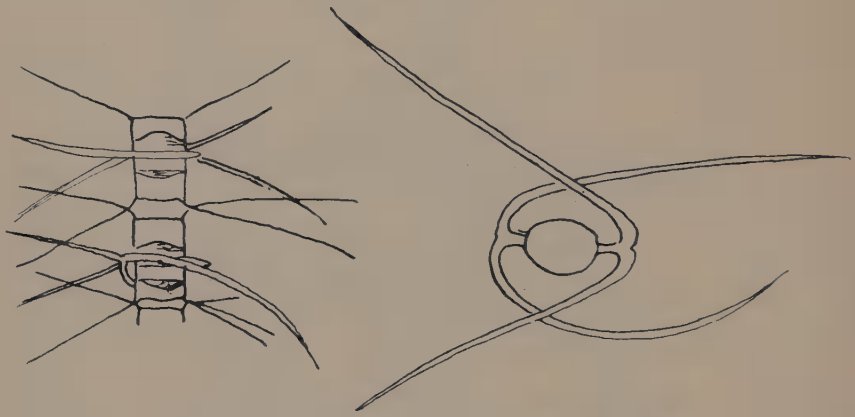


Fig. 125.—*Chætoceros cinctus* Gran. After Gran, 1897*a*.

Chætoceros furcellatus Bail., 1856.

(Fig. 126.)

Gran, Nordisches Plankton, p. 95.

Chains straight or weakly bent, without special end-cells, often surrounded by a thin slime, 8–20μ broad. Cells in broad girdle view oblong with blunt corners, not touching their neighbours. Apertures narrow, constricted in the middle. One chromatophore. Resting spores like those of *C. scolopendra* and *C. cinctus*, but with bristles which diverge at their outer part only, at a very acute angle. According to Gran it can only be distinguished from *C. cinctus* with certainty when the resting spores are present. Neritic.

Distribution.—Arctic seas, Davis Strait, Belgian coast, North Atlantic (European and American).

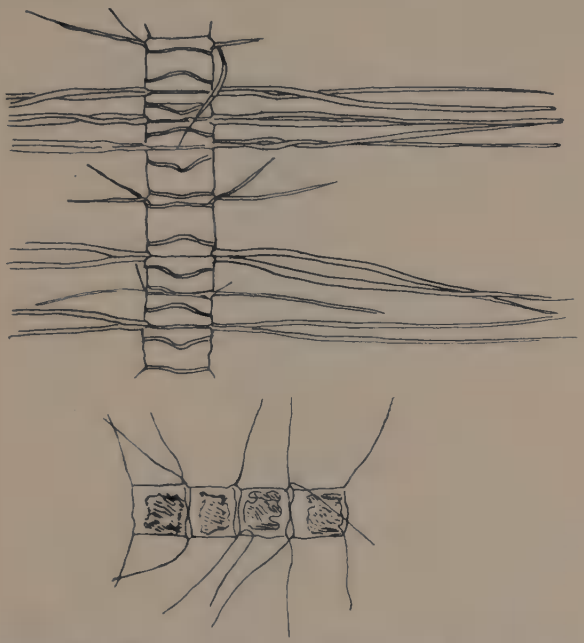


FIG. 126.—*Chætoceros furcellatus* Bail. After Gran, 1897*a*.

Chætoceros tortissimus Gran, 1900*b*.

(Fig. 127.)

Gran, Nordisches Plankton, pp. 95–96.

Chains straight or weakly bent, loose, very strongly curved round the chain axis without distinct end-cells, 11–16μ broad. Horns thin, springing from a little way within the corners, about at right angles to the chain axis, going in all directions. Cell-wall weakly siliceous. Cells in apical view rounded rectangular, the rather swollen valves touching in the middle, but not at the corners. One chromatophore situated

in the girdle region. Resting spores not known (Gran). Neritic.

Distribution.—Rather rare; North Norway, North Sea, Mediterranean.

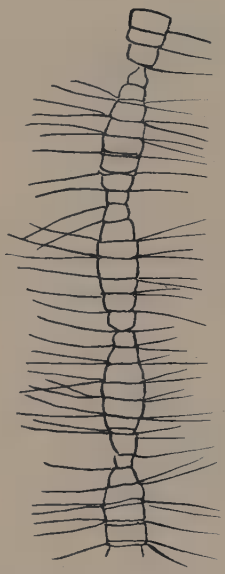


Fig. 127.—*Chætoceros tortissimus* Gran. After Gran, 1900*b*.

Section XV. Socialia.

Chætoceros socialis Lauder, 1864.

(Fig. 128.)

Gran, Nordisches Plankton, pp. 96–97.

Chains curved, many united together in large slimy circular colonies, which are held together by the slime, and often also by some very fine long bristles, which are felted together. Cells 4·5–15μ broad, in broad girdle view oblong, the corners of the neighbouring cells not touching one another. Apertures rather long, slightly compressed in the middle. Bristles hair-like, arising from just within the valve margin, base short. Usually

of the four bristles of the two neighbouring valves three are short and diverted outwards, the fourth longer and directed straight towards the centre of the colony. Long bristles not always seen. One chromatophore.

Fig. 128.—*Chætoceros socialis* Lauder, 15μ across, Plymouth (G. E. W.).

Resting spores in the middle of the mother-cell, smooth on both sides. Neritic. Northerly temperate species.

Distribution.—Arctic seas, Davis Strait, Danish seas, Skaggerak, Baltic, North Sea, Belgian coast, English Channel, North Atlantic (European and American).

Chætoceros radians Schütt, 1895.

(Fig. 129.)

Gran, Nordisches Plankton, p. 97.

Very similar to the previous species, only different in the resting spores, which are beset with small spines on

both sides according to Gran, but are smooth, with small "verrouqueures" according to Meunier. The chains are looser, the apertures almost as big as the cells, and the base of the bristles rather longer

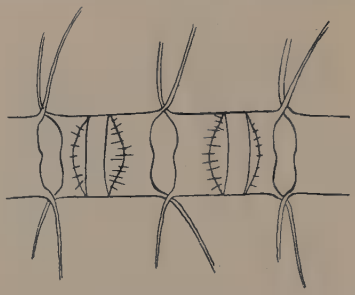


Fig. 129.—*Chætoceros radians* Schütt, 10μ across, Kattegat, with resting spores (G. E. W.).

than in *C. socialis*, 5–10μ broad. Neritic. Southerly temperate species.

Distribution.—Danish seas, Baltic, North Sea, Belgian coast.

Busch (1916) thinks it is perhaps a coastal variety of *C. socialis*.

Section XVI. Simplicia.

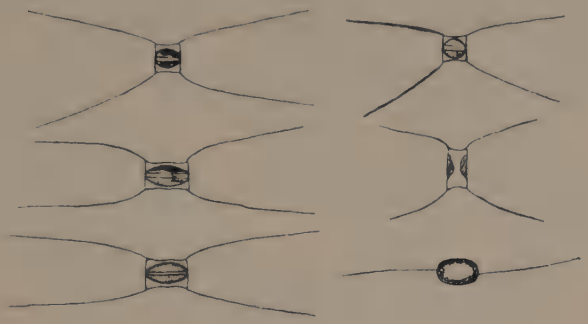
Chætoceros gracilis Schütt, 1895.

(Fig. 130*a*.)

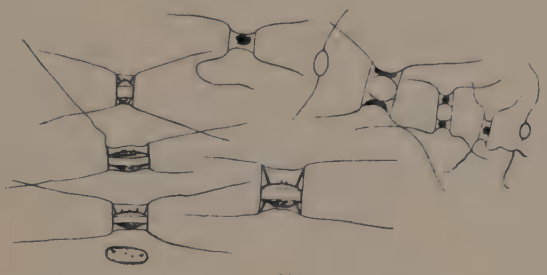
Gran, Nordisches Plankton, p. 97.

Cells single, not in chains, in broad girdle view rectangular with rather conspicuous corners and concave valves. Bristles arising from a little within the corners, curved near their origin and later becoming more nearly parallel. Two chromatophores attached to the narrow side of the girdle zone. Resting spores in the middle of the mother-cell, with rough or finely spined valves. Length of apical axis 6–10μ. Neritic.

Distribution.—Arctic Seas, Greenland Seas, Baltic, Mediterranean, California.



(*a*)



(*b*)

FIG. 130.—(*a*) *Chætoceros gracilis* Schütt, after Ostenfeld, 1910; (*b*) *Chætoceros ceratosporus* Ostenfeld, after Ostenfeld, 1912.

Chætoceros septentrionalis Oestrup.

(Fig. 131.)

Ostenfeld, 1912, p. 7.

Cells single, or two together, 4–8μ broad, mostly longer than broad; valves in side view concave with very long prominent corners, their proximal parts strongly curved, their distal parts irregularly bent and

twisted, flexible, pointing in all directions. Resting spores unknown. Formerly regarded as a variety of *C. gracilis*.

Distribution.—N.E. Greenland, Kara Sea.

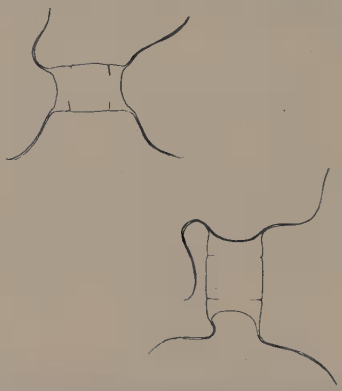


Fig. 131.—*Chætoceros septentrionalis* Œstrup, 8μ across, Arctic Sea (G. E. W.).

Chætoceros simplex Ostenfeld, 1901*a*.

(Fig. 132.)

Ostenfeld, 1901*a*, p. 137.

Cells single, or two together, 6–16μ broad, inside view rectangular with more or less undulate valve, in valve

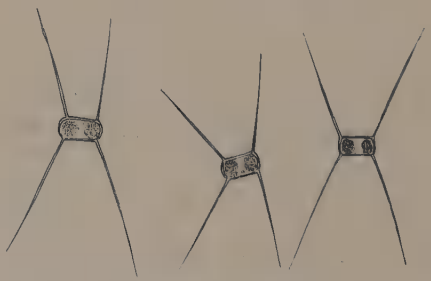


Fig. 132.—*Chætoceros simplex* Ostenf., 7μ across, from culture by Dr. Allen, Plymouth (G. E. W.).

view broadly elliptic. Valves faintly concave with a slight elevation in the middle. Bristles nearly perpendicular upon the cell in side view, more or less arched in

the proximal part. Converging or diverging distally, thin and delicate. Chromatophores 1–2, placed either in front or on the valves. Resting spores nearly globular, more or less armed with small short spines or papillæ (Ostenfeld). Neritic.

Distribution.—Mediterranean. In culture by Dr. Allen, Plymouth.

Forti (1924) describes a form *major* from the Adriatic, measuring up to 30μ across.

Chætoceros ceratosporus Ostenfeld, 1910.

(= *C. gracilis* Apstein, from Baltic.)

(Fig. 130*b*.)

Ostenfeld, 1910, p. 278.

Like *C. gracilis* but with only one chromatophore. Corners of cells in side view not contracted. Resting spores with two rather large spines on the primary valve, and often also small spines, secondary valve smooth (Ostenfeld). Neritic.

Distribution.—Baltic, Belgian coast.

Also recorded from our area in the International Fisheries Reports—*C. calvus* Cleve, *C. subsalsus* Lenin, probably incorrectly determined.

Family Biddulphiaceæ n. fam.

Cells with two or more poles, united in chains by pads of mucus from the processes, or by the processes themselves and by spines, or by the valve border. Cross section oval or polygonal, rarely circular.

Genus **BIDDULPHIA** Gray, 1832.

Usually coastal forms, often fixed. Certain species, however, are truly planktonic, but always neritic. Cells single or in chains with strongly siliceous cell-wall, not twisted round the perivalvular axis. Valves elliptical or three- or four-sided (rarely five-sided). At the corners

or at the ends of the apical axis of the ellipse more or less distinct processes may be present. On the end surfaces of the processes or on the corners of the valves are usually present very fine slime-pores from which slime-cushions are formed. This slime can hold the cells in straight or zigzag chains, or in the form of a stalk or cushion hold the cells fast on a strong foundation. In the planktonic forms the cells are usually held together by long spines or occur singly. Girdle zone of the cell sharply differentiated from the valve zone, cylindrical or prism-shaped, with numerous cross striæ, but chiefly without definite intercalary bands. Chromatophores numerous, small, lying against the cell-wall. Nucleus central. Mostly littoral, but a few species truly planktonic. Auxospores formed, also flagellated microspores.

This genus is well known from the work of Péragallo (1904–5) on the nuclear division of *B. mobiliensis*, where karyokinesis is described, and of P. Bergon (1903, 1904, 1907), who describes auxospores and microspores. Pavillard (1905) also describes auxospores. Ostenfeld (1908*b*) has shown how the tropical species *B. sinensis* has invaded this area and become a permanent member of the plankton. He has also differentiated clearly between this species and *B. regia* and *B. mobiliensis*, showing they are all three quite distinct species. Boyer (1900) has written a monograph of the genus.

Species: *Biddulphia Biddulphiana* (Smith) Boyer, *B. aurita* (Lyngb.) Bréb., *B. mobiliensis* (Bail.) Grun., *B. regia* M. Schultze, *B. sinensis* Grev., *B. granulata* Roper, *B. rhombus* (Ehr.) W. Sm., *B. obtusa* Kütz., *B. arctica* (Brightw.) Boyer, *B. favus* (Ehr.) v. Heurck, *B. alternans* (Bail.) v. Heurck, *B. vesiculosa* (Ag.) Boyer.

Biddulphia Biddulphiana (Smith) Boyer, 1900.
(Pl. III, fig. 3.)

Gran, Nordisches Plankton, p. 104.

Valves elliptical with swollen margins, strongly sculptured, in the middle mostly with a few small,

closely opposed spines; ribs 2–6. Corner processes with large rounded heads and provided with very fine pores. Girdle band with meshes in lines. Length of valve (apical axis) 50–70μ, breadth (transapical axis) 60–90μ. A bottom form, but met with in the plankton fairly frequently.

Distribution.—English Channel, Mediterranean, North Atlantic (European and American), Pacific coast of America.

Biddulphia aurita (Lyngb.), 1819.

(Fig. 133.)

Gran, Nordisches Plankton, pp. 105–106.

Cells united in straight or zigzag chains. Valves elliptical lancet-shaped in outline with circular processes

Fig. 133.—*Biddulphia aurita* (Lyngb.) Bréb., 33μ across, Plymouth (G. E. W.).

and slightly swollen centre with usually two small spines. Girdle zone sharply differentiated from the valve zone,

in girdle view right-angled. The cells united only by the mucous threads of the processes. Breadth of cell 30–80μ. Neritic and littoral. Chiefly a spring species, living near the bottom most of the rest of the year.

Distribution.—Arctic Seas, Norwegian Seas, Skaggerak, Baltic, all parts of the North Sea (European and American), English Channel, Pacific coasts of America.

Biddulphia mobiliensis (Bail.) Grun. in Van Heurck, 1880–1885.

(Fig. 134.)

Gran, Nordisches Plankton, p. 106, fig. *d* only.

This species has been much confused with *B. regia*. Even now the latter species is regarded by some authorities as a variety of *B. mobiliensis*. It has, however, been shown satisfactorily to be a distinct species by Ostenfeld (1908*b*). The figures *a*, *b* and *c* of *B. mobiliensis* given by Gran in 'Nordisches Plankton' are really *B. regia*.

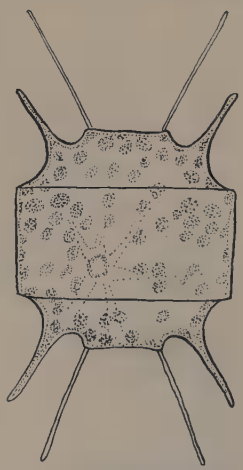


FIG. 134.—*Biddulphia mobiliensis* (Bail)., 50μ across, Plymouth (M. V. L.).

Cells single or united in short straight chains by the long spines. Relatively thin-walled, without a sharp constriction between valve and girdle zone. Valves elliptical, valve processes slender, directed diagonally outwards. Two large bristles placed far apart, but about equally far from the processes, directed obliquely outwards, straight and very wiry. Otherwise the valve is unarmed. Cell-wall with fine reticulate sculpture. Breadth 50–60μ. Neritic, and truly planktonic.

Southerly temperate species, but more northerly than *B. regia* and *B. sinensis*. Auxospores formed as large

bladders from the separation of the valves, with much larger cells inside. Microspores described by Bergon. The form described by Karsten (1905) from the Antarctic is probably a different species.

Distribution.—Norwegian seas, all parts of the North Sea, English Channel, North Atlantic (European and American), Mediterranean, Pacific coast of America.

Biddulphia regia M. Schultze, 1858.
(Fig. 135.)

Ostenfeld, 1908*b* (Gran, Nordisches Plankton, p. 106, as *B. mobiliensis*, figs. *a*, *b*, *c*).

Very like the preceding species, but the central elevated part is much wider than the depressions, flat

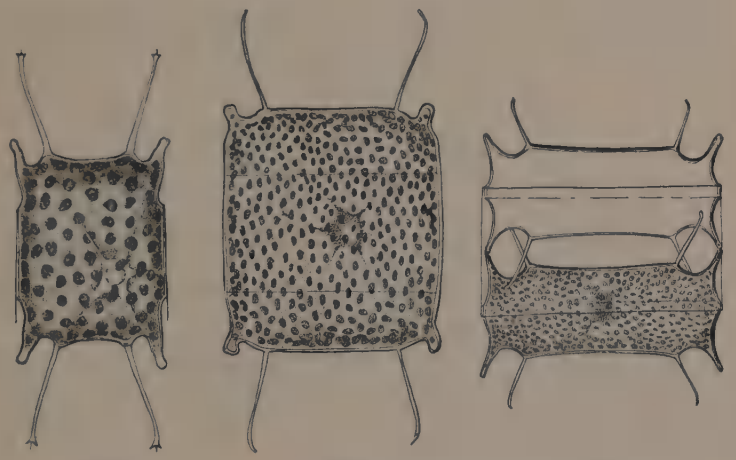


Fig. 135.—*Biddulphia regia* M. Schultze. (*a*) 140μ across; (*b*) 73μ across; (*c*) dividing, Plymouth (G. E. W.).

or faintly concave. Spines first diverging, then converging, curved, much nearer to the processes than to the centre. Processes much blunter than in *B. mobiliensis*. Depression much shallower. A fringe or membranous ridge occurs at the anterior and posterior ends

of the cell in both species. This is only seen in fresh specimens. Length 60–180μ. Neritic. Truly planktonic. More southerly than *B. mobiliensis*.

Distribution.—Southern part of North Sea, English Channel, Irish Sea. Probably has a much larger range, but has been confused with *B. mobiliensis*. The fact that Allen and Nelson grew separate cultures of *B. mobiliensis*, *B. regia* and *B. sinensis* all of which bred true for a year is strong evidence in favour of their being distinct species.

Biddulphia sinensis Grev. 1866.

(Fig. 136.)

Gran, Nordisches Plankton, p. 107, fig. as *B. mobiliensis*.
Ostenfeld 1908*b*, p. 8.

Closely related to the two preceding species, but with the processes nearly parallel to the cell axis, the spines close to the processes and about parallel to them. Length 120–240μ. Neritic. Truly planktonic.

Fig. 136.—*Biddulphia sinensis* Grev., 90μ across, Plymouth (G. E. W.).

Distribution.—All parts of the North Sea, Skaggerak, Cattegat, Irish Sea, English Channel, Indian seas, Red Sea.

This species is an Indo-Pacific form, common in the Red Sea and Gulf of Siam, which is peculiarly interesting from the fact of its sudden appearance in 1903 in Danish waters and the North Sea, and later in the Irish Sea and English Channel. Ostenfeld (1908*b*), who has investigated its distribution, supposes that it was brought by some ship to the mouth of the Elbe, where, finding a suitable breeding-place, it reproduced freely and was carried by currents north and north-east. Being able

to live in sea-water of very variable salinity and temperature it can be carried by currents for a long way through various salinities and temperatures and can be carried in the under-currents. To explain the presence of *B. sinensis* on the Belgian coast a reversal of the coastal current running usually from north to south is supposed, the current being essentially a winter and spring current, stopped, or possibly reversed in late summer. Once on the Belgian coast it gradually spread along the Channel. At Plymouth it apparently first appeared in October, 1909, and in November of the same year it was noticed at Port Erin, Isle of Man, so that a mere spreading west and north cannot be supposed. How it reached the waters of the Isle of Man is not yet known. This species has been used as a current indicator and for determination of the rate of flow of current owing to its power of living in such variable temperature and salinity.

Biddulphia granulata Roper, 1859.

(Fig. 137.)

Gran, Nordisches Plankton, pp. 107–108.

Cells usually single, somewhat smaller than in *B. mobiliensis*, apical axis 50–80μ. Differs from *B.*

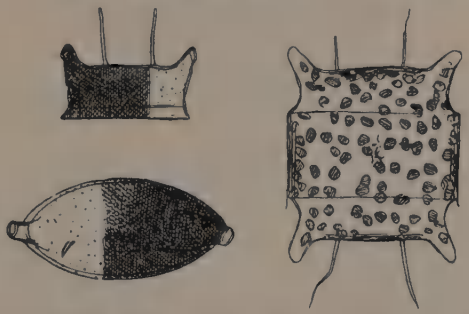


Fig. 137.—*Biddulphia granulata* Roper. After Gran, 1905.

mobiliensis in the following characters: Valve without membranous ridge, with two large spines and numerous minute thorns which are distributed over the whole

valve surface. End processes of the valve thicker. The whole cell-wall thicker. Neritic. Truly planktonic.

Distribution.—Coasts of England, North Sea, Germany, Holland, Sweden, Denmark and Belgium, American Pacific coast.

Biddulphia rhombus (Ehr.) W. Sm., 1856.

(Fig. 138.)

Gran, Nordisches Plankton, p. 108.

Cells thick-walled, rather low, strongly sculptured. Valve outline rounded rhomboid (type) or three-cornered

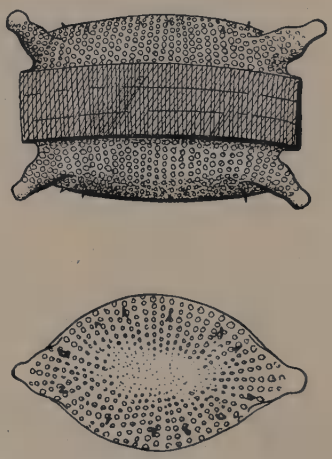


Fig. 138.—*Biddulphia rhombus* (Ehr.), 58μ across, Plymouth (G. E. W.).

(form *trigona* Cleve). Valve zone and girdle zone divided from one another by a deep groove. Girdle outstanding. Valves slightly swollen, beset with small thorns over the whole surface. Outside with a few stronger spines in the neighbourhood of the margin. Diameter 50–180μ. Neritic.

Distribution.—Coast of England, North Sea, Holland, Belgium, Germany, Sweden, Denmark, North Atlantic. (European and American).

Biddulphia obtusa Kützing, 1844.

(Fig. 139.)

Kützing, 1844, p. 137.

Cells oblong, longer than broad; no spines on valve; corners produced into thick blunt processes. Cells united in zigzag chains by cushions of mucus. A

FIG. 139.—*Biddulphia obtusa* Kützing, 35μ across, Plymouth (G. E. W.).

littoral species often occurring in the coastal plankton at Plymouth. Recorded from the Atlantic and Pacific coasts of America.

Biddulphia arctica (Brightw.), Boyer, 1900.

(Pl. III, fig. 4.)

Gran, Nordisches Plankton, p. 109.

Cell thick-walled, with short pervalvular axis. Valve outline three-cornered with straight, concave or convex

sides and rounded corners (type) or elliptical-lanceolate-shaped (form *balæna*), or intermediate stages between both forms. Valve unarmed without distinct processes, slightly swollen with reticulate sculpture arranged on a radial dichotomous linear system. The corners, out of which mucous cushions and stalks are protruded, have a distinctly finer sculpture than the other part of the valve. No constriction between valves and girdle zone. Diameter of valve 100–300μ. Littoral. Not truly planktonic.

Distribution.—Arctic Seas, Greenland, English Channel, Pacific coast of America.

Biddulphia favus (Ehr.), 1839, 41, Van Heurck, 1880–85. (Fig. 140.)

Gran, Nordisches Plankton, pp. 109–110.

Cells short, or as long as broad, cell-wall thick with strong sculpture. Cell outline regularly three-

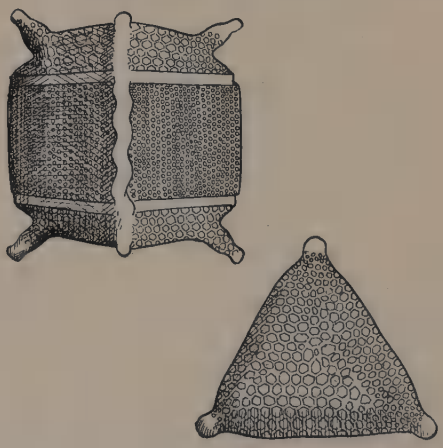


Fig. 140.—*Biddulphia favus* (Ehr.), 125μ across, Plymouth (G. E. W.).

cornered, seldom four-cornered, with sharp corners. Valve surface with large hexagonal chambers in almost straight rows. Corner processes bluntly pointed,

otherwise the valve is unarmed. No constriction between valve and girdle zone. Neritic.

Distribution.—Coasts of England, North Sea, Norway, Sweden, Denmark, Atlantic (Gulf of Mexico).

Biddulphia alternans (Bail.) Van Heurck, 1880–85.

(Fig. 141.)

Gran, Nordisches Plankton, p. 110.

Cells with short pervalvular axis; valves unarmed, in outline regularly three-cornered, rarely four-cornered, 35–50μ in diameter, with irregular ribs running over both

FIG. 141.—*Biddulphia alternans* (Bail.), 35μ across, Plymouth (G. E. W.).

valve and girdle, rather strongly punctate between the ribs. Corners hardly projecting, with very fine puncta (slime-pores). No constriction between valves and girdle zone. Neritic.

Distribution.—Coasts of England, Belgium, Holland, Sweden, Denmark, North Atlantic (European and American).

Biddulphia vesiculosa (Ag.), Boyer, 1900.

(Pl. IV, fig. 1.)

Gran, Nordisches Plankton, p. 111.

Valve outline four-cornered, seldom five-cornered, with rounded corners and more or less concave sides. Processes short, rounded. Valves unarmed. Valve surface with areolations, but the mucus-pores are only

on the heads of the processes. Constriction between valve and girdle zone shallow but distinct. Diameter of valve 50–140μ. Neritic.

Distribution.—English coasts.

Also recorded : *B. Smithii* Van Heurck, *B. turgida* Ehr., = *Cerataulus turgidus* Ehr., *B. varians* = *Bacteriastrum varians* Lauder.

Closely related forms : *Isthmia nervosa* Kütz., *I. inermis* Ehr., both littoral.

Genus **BELLAROCHIA** Van Heurck, 1880–85.

Cells in flat chains touching by their valve centres and projecting corners. Cell-wall very weakly siliceous. Chromatophores numerous.

Species : *Bellarochia malleus* (Brightw.) Van Heurck.

Bellarochia malleus (Brightw.) Van Heurck, 1880–85.

(Fig. 142.)

Gran, Nordisches Plankton, p. 111.

Usually in flat ribbon-like, rarely three-cornered chains, about 110μ broad. Valves, like the whole cell-

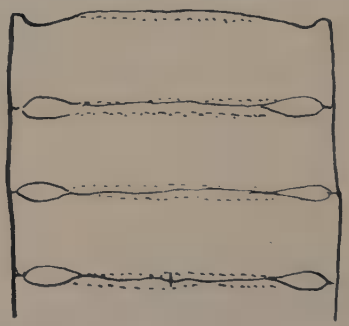


Fig. 142.—*Bellarochia malleus* Brightw. After Gran, 1905.

wall, weakly siliceous, with a rudimentary central knob and a crown of puncta on the margin. Apertures small,

broadest just inside the valve margin, further in closed by the rounded valves. Neritic. Tropical species.

Distribution.—North Sea, Atlantic coast of America, Indian Ocean.

Genus **HEMIAULUS** Ehr., 1844.

Cells single or united in chains. Valves elliptical in section, with two narrow pointed polar processes which are parallel with the cell axis. Cells more or less bent. Chromatophores numerous. Pavillard has described large auxospores in *H. chinensis* Grev.

Species : *Hemiaulus Hauckii* Grun.

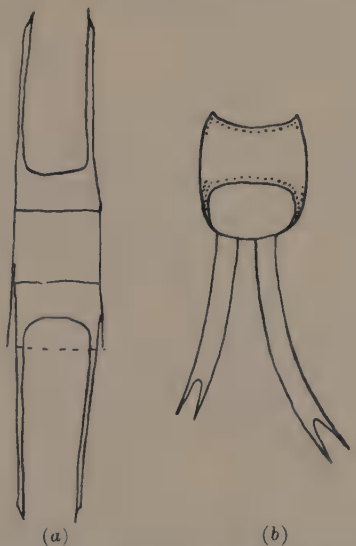


Fig. 143.—(*a*) *Hemiaulus Hauckii* Grun., after Van Heurck ; (*b*) auxospore formation in *Hemiaulus chinensis*. After Pavillard, 1905.

Hemiaulus Hauckii Grun. in v. Heurck, 1880–85. (Fig. 143.)

Gran, Nordisches Plankton, p. 100.

Cells in broad girdle view oblong with far outstanding thin processes which are strongly pointed, and by means

of which the cells hang together. Breadth of cell about 30μ. Oceanic. Temperate and tropical form.

Distribution.—Rare in English Channel; usual habitat Mediterranean; Atlantic and Pacific American, Indian Ocean.

Genus **CERATAULUS** Ehr., 1843.

Cells cylindrical, twisted round the pervalvular axis, in section elliptical or circular, valves with two stumpy processes and also with solid spines. Cell-wall strongly siliceous, with distinct sculpture. Usually littoral forms, sometimes in the plankton.

Species: *Cerataulus Smithii* Ralfs.

Cerataulus Smithii Ralfs, in Pritchard, 1861.

(Pl. IV, fig. 2.)

Gran, Nordisches Plankton, p. 102.

Valves circular in outline, equally swollen, with two conical processes near the margin, and alternating with the processes, two simple spines. Girdle zone a low cylinder bordered by a very slight constricting of the valve zone. Diameter 40–120μ.

Distribution.—North Sea coast. Rarely in plankton, singly. Atlantic coast of America.

Also recorded from this area: *C. turgidus* Ehr., a purely littoral form.

Genus **CERATAULINA** H. Pérag., 1892.

Cells cylindrical, valves slightly rounded with two stumpy processes near the margin, which hang on to the corresponding processes of the neighbouring cells by a little curved hair that fits into a sheath in the neighbouring cell. Intercalary bands numerous. Chromatophores numerous, small. Nucleus against the cell-wall, which is soft and weakly siliceous.

Species: *Cerataulina Bergonii* H. Pérag.

Cerataulina Bergonii H. Pérag., 1892.
(Fig. 144.)

Gran, Nordisches Plankton, p. 101.

Chains straight or twisted. Apertures often very small. Intercalary bands indistinct. Processes very low. Diameter 25–52μ. Neritic. Southerly temperate form. Common in Scottish lochs as well as in the sea.

Distribution.—All parts of the North Sea, Norwegian Sea, Skaggerak, Baltic, English Channel, North Atlantic (American and European), Mediterranean, California.

Fig. 144.—*Cerataulina Bergonii* H. Pérag., 40μ across, Plymouth (G. E. W.).

Genus **LITHODESMIUM** Ehr., 1841.

Cells united into straight chains by the valve border. Valve three-cornered with central spine and margin with fine puncta.

Species: *Lithodesmium undulatum* Ehr.

Lithodesmium undulatum Ehr., 1841.
(Fig. 145.)

Gran, Nordisches Plankton, p. 112.

Chains quite straight, 40–60μ broad, the cells and the portion

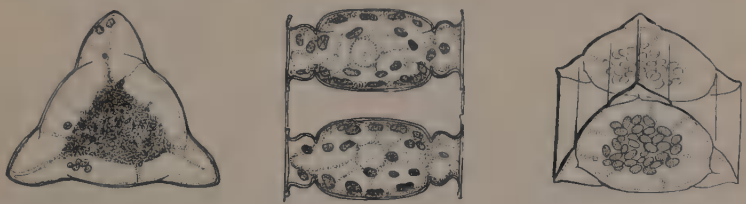


Fig 145.—*Lithodesmium undulatum* Ehr., 55μ across, Plymouth (G. E. W.).

surrounding the margin border about the same size. Valves three-cornered with undulating margin. Neritic.

Distribution.—Coasts of England, North Sea, Holland, Belgium and Germany, California.

Genus **DITYLIUM** L. Bail., 1862.

Valve three- to four-cornered, with a strong central siliceous straight hollow spine and a marginal ridge strengthened by ribs. Cells elongated, prism-shaped to cylindrical. Solitary or united in chains by the bristles. Chromatophores numerous.

Species : *Ditylium Brightwelli* (West).

Ditylium Brightwelli (West.), 1860.

(Fig. 146.)

Gran, Nordisches Plankton, p. 112.

Cells prism-shaped with strongly rounded angles, to nearly cylindrical, usually 2–3 times longer than broad. Sometimes spines on valve. Transverse diameter 25–60μ. Scale-like intercalary bands, only visible by special treatment. Neritic. Southerly temperate species.

Distribution.—Coasts of England and Scotland, North Sea, Holland, Belgium, Germany, Norway, Sweden and Denmark, North Atlantic (European and American).

Family Eucampiaceæ Schröder, 1911.

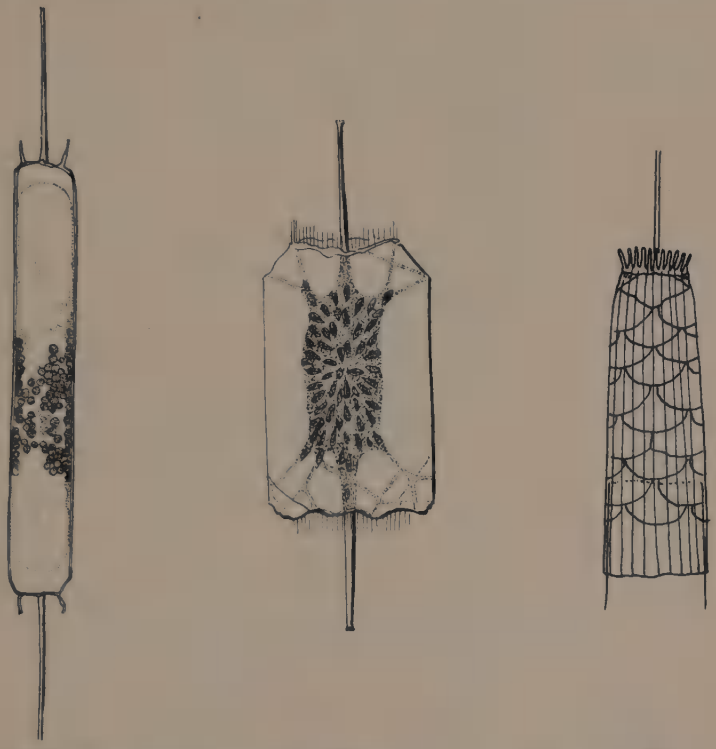
Cells very much flattened, united in chains by two processes drawn out from the ends of the valve or by the corners of a nearly flat valve. Cross-section a flattened oval.

Genus **EUCAMPIA** Ehr., 1839.

Valves elliptical in surface view with two blunt processes, but without bristles. Numerous intercalary bands

difficult to see. Chains spirally curved. Large apertures between the cells. Chromatophores numerous, small.

Species : *Eucampia zoodiacus* Ehr., *E. greenlandica* Cleve.



(*a*) (*b*) (*c*)

FIG. 146.—*Ditylium Brightwelli* (West). (*a*) 25μ across; (*b*) 60μ across, Plymouth (G. E. W.); (*c*) showing intercalary bands. After Mangin, 1908.

Eucampia zoodiacus Ehr., 1839.

(Fig. 147.)

Gran, Nordisches Plankton, pp. 98–99.

Flattened chains, spirally curved, with relatively narrow lanceolate or elliptical apertures. Chromatophores very numerous. Breadth of cell 25–73μ. Neritic. Southerly temperate form.

Distribution.—All parts of the North Sea, Baltic, Skaggerak, English Channel, Mediterranean, North Atlantic (European and American), California.

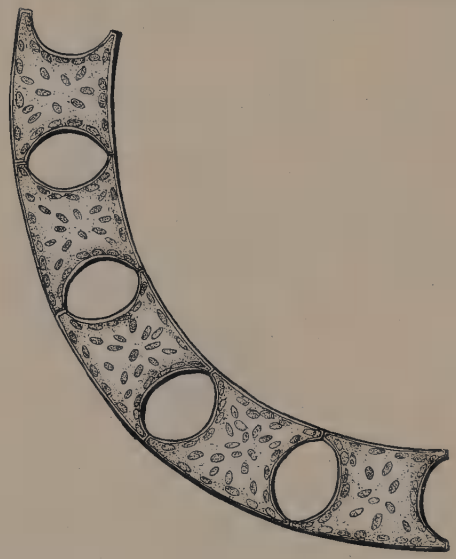


Fig. 147.—*Eucampia zoodiacus* Ehr., 25μ across, Plymouth (G. E. W.).

Eucampia greenlandica Cleve, 1896*a*.
(Fig. 148.)

Gran, Nordisches Plankton, pp. 98–99.

Chains not so spirally curved, much longer cells than in *E. zoodiacus*. Aperture nearly round. Neritic. Arctic species.

Distribution.—Arctic coasts, Davis Strait, Norwegian Seas, Skaggerak.

Genus **CLIMACODIUM** Grunow, 1868.

Chains straight with squarish oblong gaps left by the hammer-like ends of the cells, or gaps oval. Cell-wall very weakly siliceous, chromatophores numerous, small.

Species: *Climacodium Frauenfeldianum* Grun., *C. biconcavum* Cleve.

Climacodium Frauenfeldianum Grun., 1868.

(Fig. 149*a*.)

Gran, Nordisches Plankton, p. 100.

Chains with very large oblong apertures. Cell about 100μ broad. Pervalvular axis 10–15μ long. Oceanic.

Distribution.—Tropical Atlantic Ocean, northerly limit 42° north latitude.

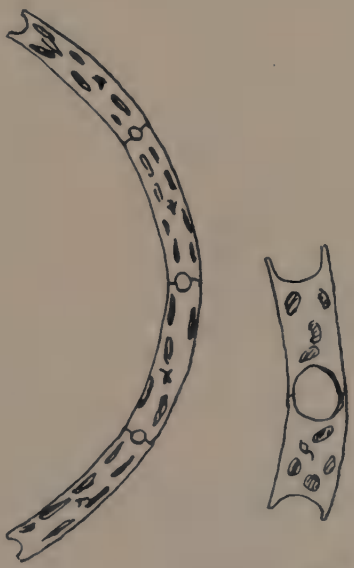


Fig. 148.—*Eucampia greenlandica* Cleve, After Gran, 1905.

Climacodium biconcavum Cleve, 1897*a*.

(Fig. 149*b*.)

Gran, Nordisches Plankton, p. 100.

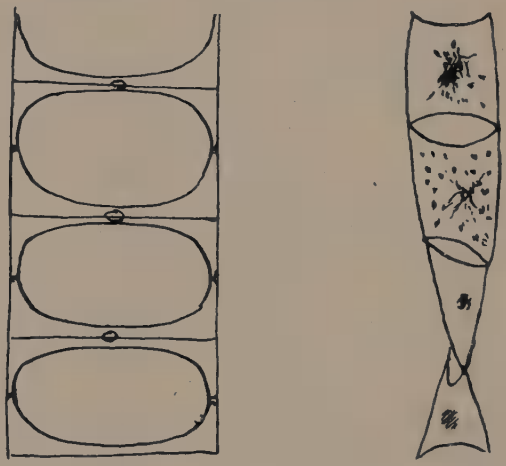
Chains straight and flat, easily contorted, 35–65μ broad. Apertures elliptic-lancet-form. Oceanic.

Distribution.—Tropical Atlantic Ocean, Mediterranean, Indian Ocean, northerly limit in Atlantic Ocean 42° north latitude.

Genus **STREPTOTHECA** Shrubs., 1890.

Cells extremely flat, with square outline, united by the valve faces, leaving hardly any aperture. Cell-wall very weakly siliceous. Chains strongly twisted. Chromatophores numerous, small. Valves narrowly elliptical with a rudimentary central knob.

Species : *Streptotheca thamensis* Shrubs.



(*a*) (*b*)

FIG. 149.—(*a*) *Climacodium Frauenfeldianum* Grun. ; (*b*) *Climacodium biconcavum* Cleve. After Cleve.

Streptotheca thamensis Shrubs., 1890.

(Fig. 150.)

Gran, Nordisches Plankton, p. 101.

Cells almost square, flat, strongly twisted (one end in relation to the other twisted about 90°). Valves not quite flat, but with two low, deeply placed knobs which fit into corresponding depressions in the neighbouring cells. Breadth 40–126μ. Neritic.

Distribution.—Arctic seas, all parts of the North Sea, Skaggerak, English Channel.

In a culture by Dr. Allen at Plymouth, round, thin-walled masses were seen issuing from the cells. Some

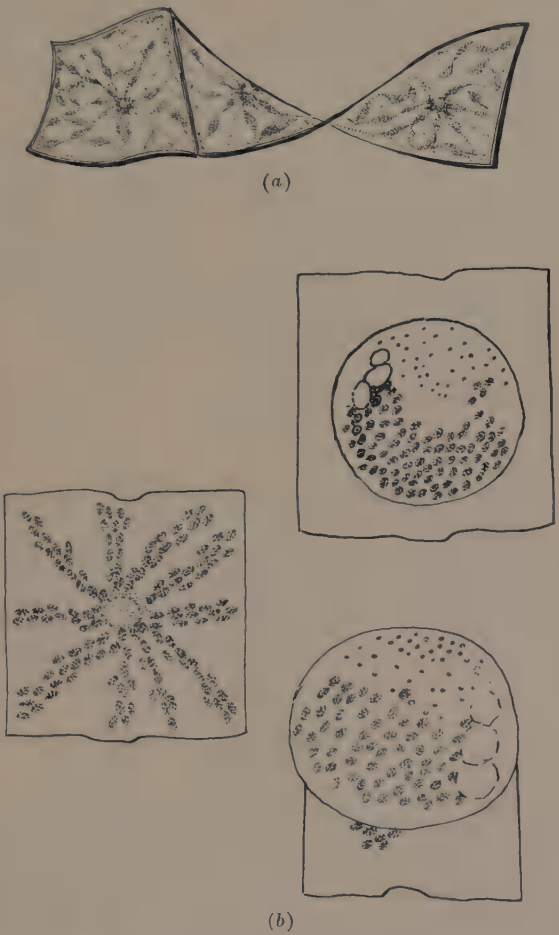


FIG. 150.—*Streptotheca thamensis* Shrubs. (*a*) 55μ across, Plymouth (G. E. W.); (*b*) 42μ across, showing (?) auxospore formation and moving spores, from culture by Dr. Allen, Plymouth (M. V. L.).

of these were full of minute moving bodies, probably microspores.

Order *PENNATÆ* Schütt, 1896.

Valves with sculpture arranged with relation to a middle line, usually with a raphe or pseudo-raphe, and if a true raphe be present the cell capable of spontaneous movement.

Comparatively few truly planktonic forms belong to this group ; those which do occur are usually in ribbon-like, star-shaped, spiral or linear chains, or entangled in extraneous mucus. The few solitary forms found in the plankton are generally not truly planktonic, but have become mixed up in the plankton from the bottom.. Typical species of some of those most frequently found in the plankton are described here.

A. With or without a pseudoraphe. Without a true raphe.

Family Fragilariaceæ Schröder, 1911.

Valves with or without a pseudoraphe, flat oval outline, cells rectangular in girdle view, often united by their valve faces, to form ribbon-like colonies. No septa.

Genus **FRAGILARIA** Lyngb., 1819.

Ribbon-like chains of cells attached by the whole of the valve faces, which in girdle view are rectangular and rod-like, in valve view elliptical lancet-form or more or less bulging in the middle. Valves flat, without or with a very rudimentary pseudoraphe, bilaterally symmetrical, with lines or rows of puncta which run more or less regularly perpendicular to the apical axis. In the middle a larger or smaller unstriated field. Chiefly littoral.

Species : *Fragilaria islandica* Grun., *F. oceanica* Cleve, *F. cylindrus* Grun.

Fragilaria islandica Grun., in Van Heurck, 1880–1885.

(Fig. 152.)

Gran, Nordisches Plankton, p. 114.

Thick, flat, straight or somewhat bent chains, 13–49μ broad. Two chromatophores in each cell, long, close to the valve. In cell division each daughter-cell has

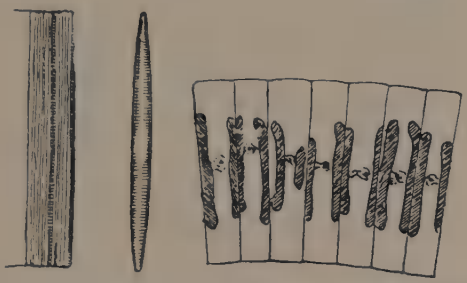


FIG. 152.—*Fragilaria islandica* Grun. After Gran, 1905.

one chromatophore which divides later. In the two species following the chromatophores divide at the same time as the cells (Gran). Valves very finely striated, narrow and sharp. Arctic-neritic. Probably not truly planktonic.

Distribution.—Arctic coasts (Jan Mayen, Barents Sea, Murman Sea, North Norway).

Fragilaria oceanica Cleve, 1873*a*.

(Fig. 153.)

Gran, Nordisches Plankton, p. 114.

Ribbon-like, straight or spirally twisted chains. Every cell with two chromatophores against the girdle, one on each side of the nucleus. Girdle view rectangular. Valve view elliptical lancet-form. Valves only striated at the margin, otherwise smooth. Resting spores in pairs in two sister-cells, the valves of the cells holding them slightly swollen. Breadth of cell 8–40μ. (Gran). Arctic neritic. Gran recognizes four different forms.

Distribution.—Usually on the coasts and among ice in Polar seas. Known from Davis Strait, Russia, Norway, Denmark and England, Gulf of Maine.

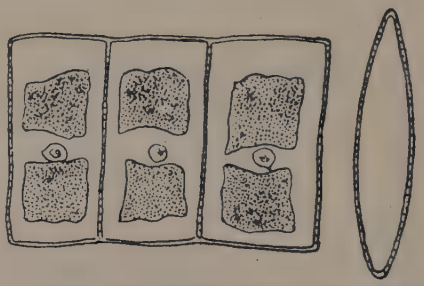


FIG. 153.—*Fragilaria oceanica* Cleve. After Gran, 1905.

Fragilaria cylindrus Grun., 1884.

(Fig. 154.)

Gran, Nordisches Plankton, p. 115.

Very like the preceding species, differing in valve view, which is linear with rounded ends. Striæ running

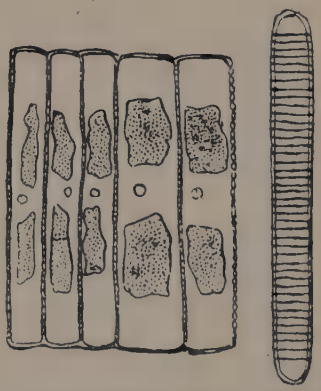


FIG. 154.—*Fragilaria cylindrus* Grun. After Gran, 1905.

across, leaving no median clear space. Breadth 6–32μ (Gran). Arctic-neritic.

Distribution.—On the coasts and between the floating ice of the North Polar seas. Not so common as the previous species.

Gran (pp. 113–114) also describes *Fragilaria crotonensis* (A. M. Edwards) Kitton, freshwater but found in the Baltic plankton, and *F. striatula* Lyngb. (Fig. 151), littoral on European coasts and sometimes in the plankton.

Also recorded : *F. capucina* Desm., freshwater.

The following littoral and freshwater forms are recorded which are closely related to *Fragilaria* : *Synedra acus* Kütz., *S. affinis* Kütz., *S. arcuata* (Näg.), *S. delicatissima* W. Sm., *S. longissima* W. Sm., *S. pulchella*

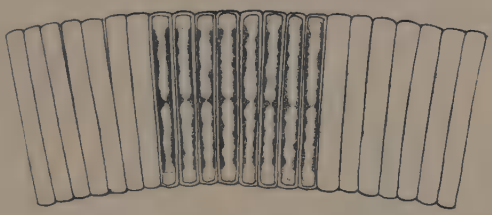


Fig. 151.—*Fragilaria striatula* Lyngb., 55μ broad, Plymouth (G. E. W.), littoral form.

Kütz., *S. ulna* (Nitzsch) Ehr., *S. undulata* (Bail.) Greg., *Cymatosira belgica* Grun., *Campylosira cymbelliformis* (A. Sch.) Grun., *Raphoneis amphiceros* Grun., *R. belgica* Grun., *R. surirella* (Ehr.) Grun.

Genus **ASTERIONELLA** Hassal, 1845.

Cells rod-like with distinctly dissimilar ends, united into star-like or spiral colonies in which the cells hang together only by the thicker ends. Valve with a median pseudoraphe.

Species : *Asterionella japonica* Cleve and Möller, *A. kariana* Grun., *A. notata* Grun., *A. Bleakeleyi* W. Sm.

Asterionella japonica Cleve & Möller, 1877–1882.

(Fig. 155.)

Gran, Nordisches Plankton, p. 118.

Colonies star-shaped, in close spirals. Inner part of cell in girdle view three-cornered with one or two

chromatophores, outer part hair-like without chromatophores. Breadth of cell 50–85μ. Length of inner thicker part 12–15μ. Neritic, southerly temperate species.

Distribution.—Coasts of England, English Channel, Scotland, Holland, Belgium, Germany, Sweden, Den-

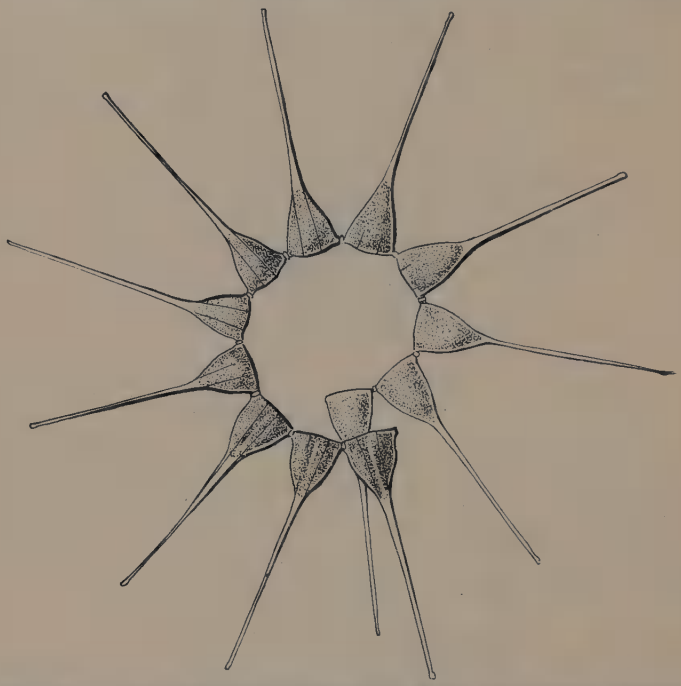


Fig. 155.—*Asterionella japonica* Cleve and Möller, 58μ broad, Plymouth (G. E. W.).

mark, Mediterranean, North Atlantic (European and American), California; sometimes very abundant. Occurring in swarms, Herdman, Scott and Lewis (1914), Bigelow (1926).

Asterionella kariana Grun., Cleve & Grun., 1880.

(Fig. 156.)

Gran, Nordisches Plankton, pp. 118–119.

Colonies spiral with a large circular radius. Cells at the base broad, suddenly narrowing, then again

widening, thinning out from the middle to the end. Several chromatophores in each cell. Breadth of cell = length of valve, 37–68μ. Neritic.

Distribution.—Arctic Seas (Kara and Murman Seas), North Atlantic (Irish Sea), California.

Asterionella notata Grun., Van Heurck, 1880–1885.

(Fig. 158.)

Gran, Nordisches Plankton, p. 119.

Chains not star-shaped, but in spirals which are much more elongated and less apparent than in *A. japonica*, and pieces of the chain broken off may be straight.

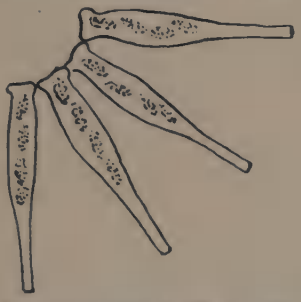


FIG. 156.—*Asterionella kariana* Grun., valve 64μ long, Rhos-on-Sea (M. V. L.).

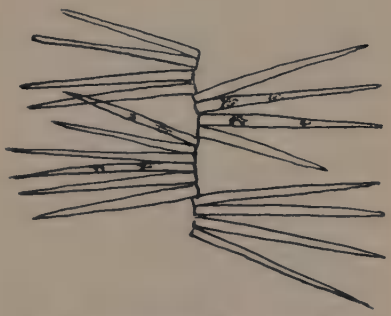


FIG. 158.—*Asterionella notata* Grun. After Pavillard, 1925.

The cells in a chain may diverge in different directions. Valves broad at one end, the rest linear with almost parallel sides. Chromatophores scattered in the whole cell. Length of valve 50–100μ. Neritic.

Distribution.—Coast of the Atlantic and Mediterranean, northerly limit 40° north latitude, Barbados, common.

Asterionella Bleakeleyi W. Sm., 1853–56.

(Fig. 157.)

Gran, Nordisches Plankton, p. 119.

Star-like colonies. Cell wide at the base and apex, thin in the middle (Gran). Length of valve about 55μ. Neritic and littoral.

Distribution.—Coasts of the North Sea, Barbadoes.

Also recorded: *Asterionella formosa* Hassal, and *A. gracillima* (Hentsch.), freshwater.

Closely related forms: *Diatoma tenue* (Ag.), = *D. elongatum* v. *tenue* Ag., *D. vulgare* v. *constricta* Grun. All freshwater forms.

Genus **THALASSIOTHRIX** Cleve & Grun., 1880.

Cells rod-shaped, straight or slightly bent, single or united into star-like or zigzag colonies. Valves linear, without pseudoraphe, with similar or slightly different poles which hold the cells together. Chromatophores numerous, small.

Species: *Thalassiothrix longissima* Cleve & Grunow, *T. Nitzschioides* Grun., *T. Frauenfeldii* (Grun.), Cleve & Grun.

Thalassiothrix longissima Cleve & Grun., 1880.

(Fig. 159.)

Gran, Nordisches Plankton, pp. 116–117.

Single, thread-shaped cells. Valves very long, up to 3–4 mm., slightly curved, with slightly dissimilar poles. Boreal-Arctic oceanic species. Often in great quantities.

Distribution.—Arctic seas, North Sea, coasts of Scotland, Belgium, Russia, Germany, Norway, Sweden, Denmark, Mediterranean, North Atlantic (European and American), California, Antarctic.

Thalassiothrix Nitzschioides Grun., Van Heurck, 1880–1885.

(Fig. 160.)

Gran, Nordisches Plankton, p. 117.

Cells united into star-like or zigzag chains, straight, slightly curved, or rarely, as an abnormality, bent. In girdle view elongated rectangular, in valve view linear or very narrow lancet-shaped. Both poles of the valves

alike. Length of valve very variable, 10–80μ. Neritic. North temperate species.

Distribution.—Coasts of England, North Sea, Holland,

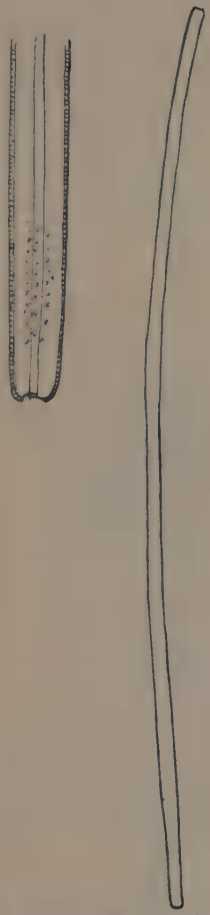


Fig. 159.—*Thalassiothrix longissima* Cleve and Grun., valve 1 mm. long, N. Atlantic, "Scotia" material (M. V. L.).

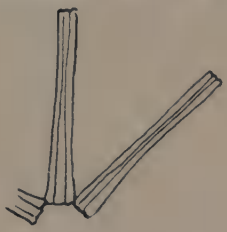


Fig. 157.—*Asterionella Bleakeleyi* W. Sm. After Van Heurck.

(*a*)

(*b*)

Fig. 160.—*Thalassiothrix Nitzschioides* Grun. (*a*) valve 80μ long; (*b*) 22μ long, Plymouth (G. E. W.).

Russia, Norway, Sweden, Denmark, Germany, Finland, Mediterranean, North Atlantic (European and American), California.

Thalassiothrix Frauenfeldii (Grun.) Cleve & Grun., 1880.

(Fig. 161.)

Gran, Nordisches Plankton, pp. 117–118.

Both poles of valves distinct, but only slightly dissimilar. Colonies always star-shaped (mucous cushions only present at one morphologically recognizable end of the cell). Valves rather long, up to 100μ, otherwise like the previous species (Gran). Oceanic. Temperate.

Distribution.—Coasts of England, Scotland, Belgium, Russia, Germany, Norway, Sweden, Denmark, Mediterranean, American North Atlantic.

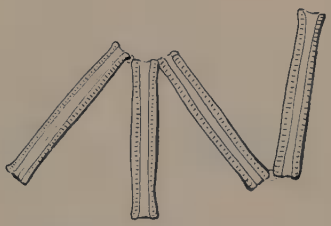


Fig. 161.—*Thalassiothrix Frauenfeldii* (Grun.), valve 40μ long (G. E. W.).

Fig. 162.—*Striatella unipunctata* Ag., 65μ long, Plymouth (G. E. W.).

Family Tabellariaceæ West, 1927.

With or without median pseudoraphe. Cells straight, oblong or square in girdle view. Usually united to form ribbon-like or zigzag chains. Two or more longitudinal septa.

Genus **STRIATELLA** Agardh, 1830–1832.

Cells oblong, rectangular, cut off at the corners, cohering by mucous cushions in zigzag chains, the bottom cell on a fixed stalk. Many intercalary bands, septa alternate. Valves lancet-form with pseudoraphe, oblique or nearly straight. Chiefly bottom forms, but fairly often in coastal plankton.

Typical species : *Striatella unipunctata* Ag. (Fig. 162).

Genus **GRAMMATOPHORA** Ehr., 1839.

Cells oblong, adhering by their opposite and alternate angles, or, more rarely, by their adjacent angles, into zigzag or star-like chains. Septa opposite, curved. Valves linear or elliptical. Littoral, but often in coastal plankton. Auxospores known (Fig. 4).

Species : *Grammatophora serpentina* Kütz., *G. marina* Kütz.

Grammatophora serpentina Kütz., 1844.

(Fig. 163*b*.)

W. Smith, 1856, p. 43.

Septa with two or more curvatures. Valves striated, linear, rather thinner towards the extremities, which

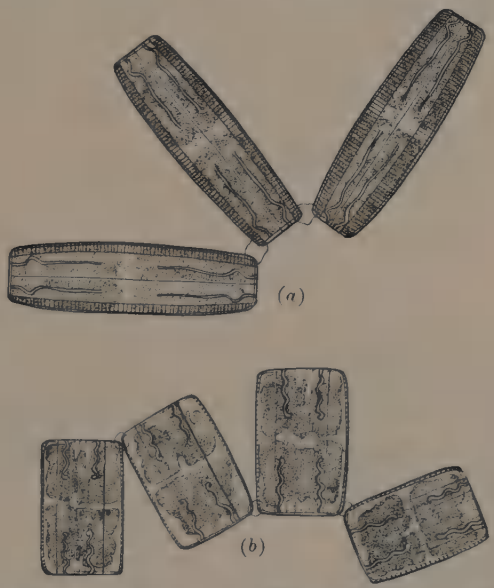


Fig. 163.—(*a*) *Grammatophora marina* Kütz., valve 58μ long ; (*b*) *Grammatophora serpentina* Kütz., valve 18μ long, Plymouth (G. E. W.).

are obtuse or rounded. Valve length 18 to 127μ. Neritic and coastal. South temperate species.

Distribution.—Common on European coasts, Atlantic North America.

Grammatophora marina Kütz., 1844.

(Fig. 163*a*.)

W. Smith, 1856, p. 42.

Septa with a single curvature near the margin of the cell. Valve elliptical or linear, with slightly swollen ends. Valve length 10–104μ. Neritic and coastal. South temperate species. Auxospores observed by Ed. Milton (Fig. 4).

Distribution.—Coast of Europe, Atlantic and Pacific America.

Also recorded : *Grammatophora oceanica* Ehr.

Genus **RHABDONEMA** Kütz., 1844.

Cells in filamentous chains, quadrangular, with numerous septa and transverse rows of puncta. Valves elliptical or linear-lanceolate, with pseudoraphe and transverse ribs and punctate lines. Chromatophores in rosettes, each with a pyrenoid.

Species : *Rhabdonema adriaticum* Kütz.

Rhabdonema adriaticum Kütz., 1844.

(Fig. 164.)

W. Smith, 1856, p. 35.

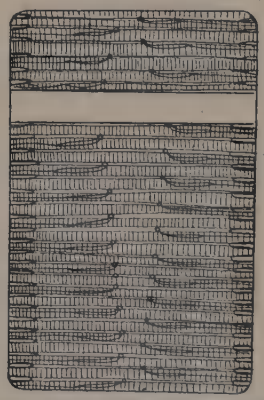


Fig. 164.—*Rhabdonema adriaticum* Kütz,. 125μ long, Plymouth (G. E. W.).

Valves linear-lanceolate, septa curved and somewhat thickened at the ends. Length of valve *ca.*95 to 125μ. Auxospores known (Fig. 5). Coastal form. South temperate.

Distribution.—Atlantic (European and American), American Pacific, England, Mediterranean.

Also recorded : *Rhabdonema arcuatum* (Lyngb.) Kütz., *R. minuta* Kütz.

Closely related: *Athya Zachariasi* J. Brn.

Genus **LYCMOPHORA** Agardh, 1830–1832.

Cells in girdle view three-cornered, attached by mucous stalks to algæ, hydroids, etc. In the littoral zone, but also attached to living plankton (especially copepods), or to suspended dead matter in the open sea. Valves at one (the lower) end narrow and pointed, at the upper end broader, usually rounded, with a middle pseudoraphe. Girdle zone with intercalary bands, one of which in each valve pierces the cavity like a septum above whilst below it is open.

Species : *Lycmophora Lyngbyei* (Kütz.) Grun.

Lycmophora Lyngbyei (Kütz.) 1844 ; Grun., Van Heurck, 1880–1885.

(Fig. 165.)

Gran, Nordisches Plankton, p. 120.

Girdle view three-cornered, with both upper corners rounded, the lower (fixed) cut off straight. Mucous

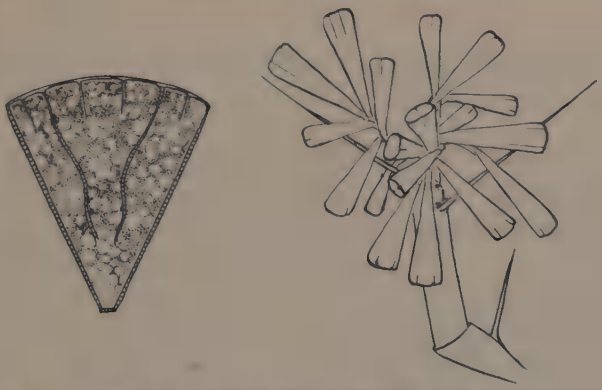


Fig. 165.—*Lycmophora Lyngbyei* (Kütz.), valve 60μ long, Plymouth, attached to leg of copepod (G. E. W.).

stalks dichotomously branched. Valves club-shaped, with distinct pseudoraphe and fine striæ perpendicular to it. Septa projecting into the cell for about one-eighth

of the valve length. Chromatophores numerous. Length of valve 50–75μ. Neritic and littoral.

Distribution.—European coasts, N. American Atlantic and Pacific coasts.

B. With raphe on one valve only. Pseudoraphe on the other.

Family ACHNANTHACEÆ West, 1927.

Cells in girdle view crooked or bent. Valves with true raphe on one valve and pseudoraphe on the other. Fixed by a stalk which may hold several cells attached to one another by the valve faces.

Genus **ACHNANTHES** Bory, 1822.

Cells united in ribbon-like chains and borne on a mucous stalk. Valves elliptical or lancet-form, dissimilar, with raphe and central nodule on one, the other with a pseudoraphe. Chiefly littoral.

Species: *Achnanthes tæniata* Grun., *A. longipes* Agardh.

Achnanthes tæniata Grun., Cleve & Grun., 1880.

(Fig. 167.)

Gran, Nordisches Plankton, p. 122.

Cells thickly united in long ribbon-like chains which are like *Fragilaria*. Valves flat or slightly rounded, those with central nodules outside. One chromatophore in each cell, close to girdle, H-shaped. Resting spores may be formed. Breadth of chain 11–40μ (Gran). Littoral or neritic. Arctic species.

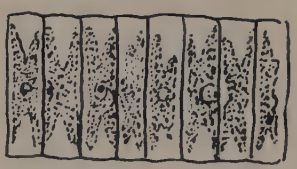


FIG. 167.—*Achnanthes tæniata* Grun. After Gran, 1905.

Distribution.—Sea of Kara, Baffin's Bay, Davis Strait, Finland, Denmark, Sweden, Germany.

Achnanthes longipes Agardh, 1824.
(Fig. 166.)
W. Smith, 1856, p. 26.

Chains of few cells borne on a long stalk attached to various algæ. Valves with strong ribs and striæ of puncta like small chains. Length of valve 75μ, breadth 38μ. Littoral, but often found in coastal plankton.

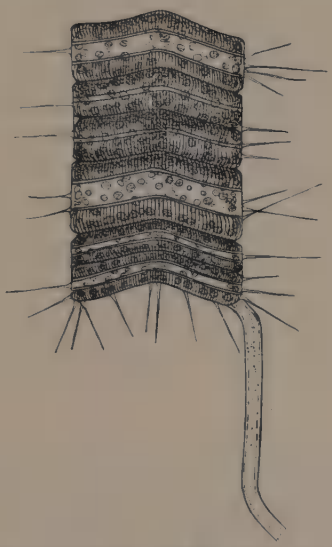


FIG. 166.—*Achnanthes longipes* Agardh, valve 75μ long, Plymouth (G. E. W.).

Distribution.—Coasts of England, Ireland, Denmark, N. Atlantic (European and American).

Closely related and recorded: *Cocconeis pediculus* Ehr., *C. scutellum*, both littoral.

c. With a true raphe on both valves.

Family NAVICULACEÆ West, 1927.

Valves usually straight, with a straight raphe, a central and two polar nodules. More rarely oblique. Girdle view usually rectangular.

Genus **NAVICULA** Bory, 1822.

Cells usually free, capable of movement, but in planktonic forms usually united into ribbon-like chains.

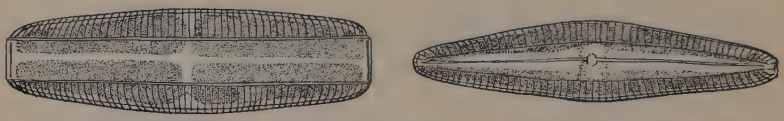


Fig. 168.—*Navicula* sp., typical bottom form, valve 95μ long, Plymouth (G. E. W.).

Both valves with raphe and central nodule. Chromatophores two. Auxospores formed.

Species : *Navicula membranacea* Cleve, *N. septentrionalis* Grun., *N. Granii* Jörd., *N. pelagica* Cleve, *N. Vanhöffeni* Gran.

Navicula membranacea Cleve, 1897*a*.

(Fig. 169.)

Gran, Nordisches Plankton, pp. 123–124.

Short, thick, straight, ribbon-like chains, 50–90μ broad. Valves flat, lancet-form, with a thickening in

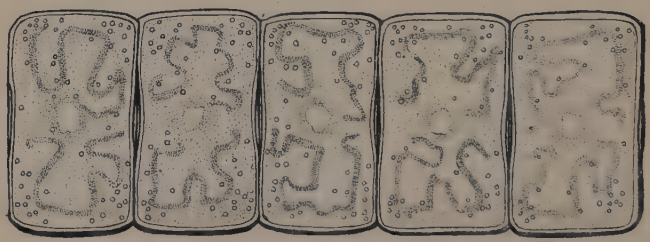


Fig. 169.—*Navicula membranacea* Cleve, 53μ broad, Plymouth (G. E. W.).

the middle perpendicular to the raphe. Cells in girdle view rectangular. Girdle zone striated. Cell-wall thin, weakly siliceous. Two chromatophores drawn out like a ribbon with several pyrenoids. Neritic, but truly planktonic.

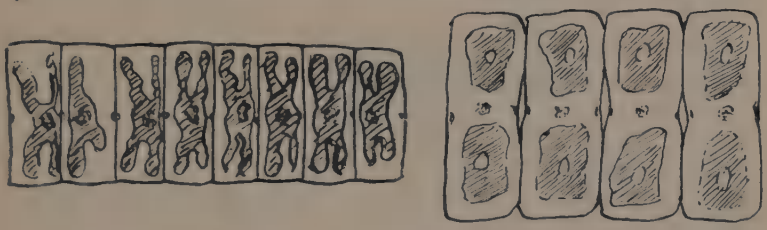
Distribution.—Coasts of England, Holland, Belgium, Sweden, Mediterranean.

Navicula septentrionalis (Grun.), 1884.

(Fig. 170*a*.)

Gran, Nordisches Plankton, p. 124.

Long, ribbon-like chains of 20–30μ breadth, in which the cells touch one another by the whole valve face. These are, however, sometimes separated by a gelatinous substance. Valves narrow, linear with rounded ends, with conspicuous raphe and central capsule, which is widened out into a *stauros* at right angles to the raphe. One chromatophore, placed near the girdle with a large central pyrenoid and four arms, which show up against



(*a*) (*b*)

Fig. 170.—(*a*) *Navicula septentrionalis* (Grun.), 20–30μ broad. After Gran, 1905; (*b*) *Navicula Granii* (Jörgensen). After Gran, 1905.

the valve ends and are often for a space parallel with the valve (Gran).

Distribution.—Arctic neritic species, Greenland, Davis Strait, Barents and Murman Seas.

Navicula Granii (Jörgensen), 1905*a*.

(=*Stauroneis Granii* Jörgensen, 1905*a*.)

(Fig. 170*b*.)

Gran, Nordisches Plankton, p. 124.

Ribbon-like chains, 50–57μ broad, in which the cells touch one another by most of the valve faces. In the living condition they do not touch at the ends, and in the middle the valves are indented so as to leave gaps

between adjacent cells. Two chromatophores, large square plates, each with a pyrenoid. Valve with a median space (*stauros*) (Gran). Neritic, arctic form.

Distribution.—Greenland, Murman Sea, Barents Sea.

Navicula pelagica Cleve, 1896*a*.

(Fig. 171.)

Gran, Nordisches Plankton, p. 125.

Chains of small rod-shaped cells which appear as though they were strung on a thread, as they only hang together by the valve centres with their ends in all

Fig. 171.—*Navicula pelagica* Cleve, After Gran, 1905.

directions. Length about 15μ. Two chromatophores near the girdle (Gran). Neritic. Arctic form.

Distribution.—Greenland, Murman Sea, Barents Sea.

Navicula Vanhöffeni Gran, 1897*b*.

(Fig. 172.)

Gran, Nordisches Plankton, p. 214.

Long, often slightly bent, ribbon-like chains, 29–45μ broad, in which the cells do not touch one another, but are united by a band of mucus. Valves narrowed at the ends and in the middle. Slightly swollen between the middle and ends (Gran). Neritic, Arctic.

Distribution.—Coasts of England, Denmark, Finland.

These five species in chains are truly planktonic forms. The free forms found in the plankton are almost certainly littoral or bottom species which have been brought up temporarily into the plankton (Fig. 168).

Also recorded : *Navicula distans* W. Sm., single in deep water, *N. Smithii* Bréb., *N. crabro* Ehr., *N. Weissflogi* A. Schm., littoral, *N. lyra* Ehr., brackish water, *N. algida*, *N. kryophila* Cleve, *N. detersa* (Grun.), *N. subinflata* Grun., *N. gelida* Grun., Arctic littoral forms.

FIG. 172.—*Navicula Vanhöffeni* Gran. After Gran, 1897.

Closely related : *Cymbella lanceolata* Ehr., *Diploneis fusca* Greg., *D. littoralis* (Donk.), *Epithemia turgida* (Ehr.) Kütz. (= *Cymbella turgida*), *Eunotia angulata*, *Gomphonema angulata* Östrup, *Rhicosigma arcticum* Cleve, *Scoliopleura latistriata* Grun., *S. tumida* (Bréb.), *Trachyneis aspera* Ehr., *Tropidoneis lepidoptera* Greg.

Genus **GYROSIGMA** Hassal, 1845.

(=*Pleurosigma* W. Sm., 1853-56.)

Cells free, elongated. Valves curved in an **S** shape with curved central raphe, and central and end nodules.

FIG. 173.—*Gyrosigma* sp., valve 75μ long, Plymouth (G. E. W.).

Otherwise like *Navicula*. Nearly all bottom forms but often occurring in the plankton.

Species recorded : *Gyrosigma angulatum* W. Sm., *G. fasciola* (Ehr.) Cleve. Typical species figured (Fig. 173.)

Genus **AMPHIPRORA** Ehr., 1843.

Cells single or in ribbon-like chains. Valves with raphe, central nodule and keel which is twisted into an **S**, so that one half lies on each side of the chain axis. One chromatophore. Littoral and neritic.

Species: *Amphiprora hyperborea* (Grun.).

Amphiprora hyperborea (Grun., Cleve & Grunow), 1880.

(Fig. 174.)

Gran, Nordisches Plankton, p. 129.)

Ribbon-like, often slightly twisted chains, 58–110μ broad. Cell with the chromatophore near the girdle

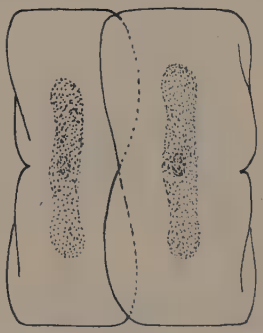


Fig. 174.—*Amphiprora hyperborea* (Grun.), 70μ broad, North Atlantic, "Scotia" material (M. V. L.).

containing a pyrenoid. Cell-wall thin, weakly siliceous, with hardly perceptible sculpture. Valve with a slightly **S**-shaped keel (in valve view), which in the chain in girdle view covers half the keel of the neighbouring cell, which itself is half covered. Several intercalary bands. Neritic Arctic form.

Distribution.—Northern Atlantic, Greenland, Barents Sea, Murman Sea, N. Norway.

Also recorded: *Amphiprora alata* Kütz., *A. Kjellmanni* Cleve, *A. kryophila* Cleve.

Family NITZSCHIACEÆ Schröder, 1911.

Raphe in each valve on a keel with puncta at the edges. No nodules. Cells rhombic in transverse section.

Genus **BACILLARIA** Gmel., W. Sm., 1856.

Cells rod-like, the shape of wooden matches, united in movable bands, each cell moving on its neighbour. Otherwise like *Nitzschia*.

Species: *Bacillaria paradoxa* Gmel.

Bacillaria paradoxa Gmel., van Heurck, 1880-1885. (Fig. 175.)

Gran, Nordisches Plankton, p. 131.

Valves 85–250μ long, 5–6μ broad. In girdle view narrow rectangular, in valve view linear with pointed

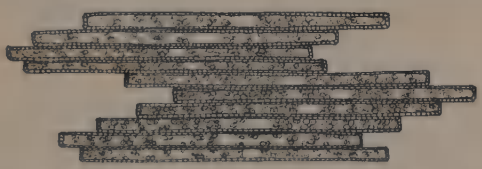


FIG. 175.—*Bacillaria paradoxa* Gmel., valve 150μ long, Plymouth (G. E. W.).

ends. Cells united in movable colonies, in which the cells slide quickly along one another. Chromatophores two, one on each side of the nucleus. Neritic, coastal form.

Distribution.—European coasts, Californian coasts.

Genus **NITZSCHIA** Hassal, 1845.

Cells spindle-shaped, single or united in colonies. Valves with raphe but no central nodule. Chromatophores two. The keels of the two valves diagonally opposite.

Species: *Nitzschia closterium* (Ehr.), *N. frigida* Grun., *N. seriata* Cleve, *N. delicatissima* Cleve.

Nitzschia closterium (Ehr.), 1839.

(Fig. 176.)

Gran, Nordisches Plankton, p. 129.

Cells living singly, freely movable, with hair-like bent ends into which the chromatophores do not extend. Usually slightly bent in a semicircle. Length of valve 20–90μ. Usually near the shore in slimy algal colonies. Neritic.

Distribution.—Ubiquitous along the coasts; known from Davis Strait, England, Scotland, Norway, Sweden, Denmark, California.

Fig. 176.—*Nitzschia closterium* (Ehr.), valve 42μ long, Plymouth (G. E. W.).

This species has peculiar interest because it is the form used commonly by Dr. Allen of the Plymouth Laboratory for culture. There pure cultures are kept up continually and are used for food when rearing minute planktonic animals.

Nitzschia frigida Grun., in Cleve & Grun., 1880.

(Fig. 177.)

Gran, Nordisches Plankton, p. 129.

Cells spindle-shaped, with rounded ends, united in tree-like branched colonies (Gran). Length of valve 45–75μ. Arctic. Neritic. On ice.

Distribution.—Arctic coastal species. Not a true plankton form. Known from the Arctic coast and the Inner Baltic.

Nitzschia seriata Cleve, 1883.

(Fig. 178.)

Gran, Nordisches Plankton, pp. 129–130.

Cells spindle-shaped, with rounded ends, united in stiff, hair-like chains, formed so that the cells lie together

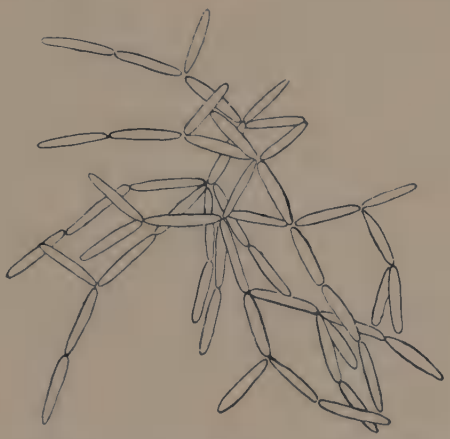


Fig. 177.—*Nitzschia frigida* Grun. After Gran, 1897.

for a short way along their points. Length of valve about 100μ, breadth about 6μ. Neritic. Widely distributed in open seas and along the coasts and also in

Fig. 178.—*Nitzschia seriata* Cleve, valve 90μ long, Plymouth (G. E. W.).

the Scottish lochs. Probably a neritic species of Northern but not Arctic character.

Distribution.—Known from Davis Strait, England, Scotland, Holland, Belgium, Germany, Norway, Sweden, Denmark, American Atlantic and Pacific coasts, Antarctic ?

Nitzschia delicatissima Cleve, 1897*a*.

(Fig. 179.)

Gran, Nordisches Plankton, p. 130.

Very similar to the previous species, only much more slender. Cells hair-like, about 1·5μ across. Neritic.

Distribution.—The same as *N. seriata* but more restricted.

Fig. 179.—*Nitzschia delicatissima* Cleve, 1·4μ across, Plymouth (M. V. L.).

Also recorded: *Nitzschia Brébissonii* W. Sm., *N. borealis* Grun., *N. polaris* Grun., Arctic forms; *N. insignis* Greg., *N. longissima* Ralfs, *N. panduriformis* Greg., littoral forms; *N. paravasa* Grun., *N. nigrans*, *N. sigma* W. Sm., brackish-water forms; *N. sigmoidea*, *N. tenuissima*, freshwater forms.

Family Surirellaceæ West, 1927.

Each valve with a pseudoraphe and spreading marginal wings containing a simple raphe (two to each valve) without nodules. Valves often with strong ribs.

Genus **SURIRELLA** Turp., 1827.

Cells single, oval or linear. Valves with a longitudinal central pseudoraphe and margins produced into wing-like expansion containing the raphe each side. Pseudoraphe of one valve parallel to that of the other. Distinct canal-pores usually seen. Bottom and littoral forms occasionally met with in the plankton. Capable of violent spontaneous movement. Figure of typical species Fig. 180.

Genus **CAMPYLODISCUS** Ehr., 1841.

Cells single, saddle-shaped. Valves with a longitudinal central pseudoraphe, that of one valve at right angles to that of the other. Canal-pores distinct, usually in parallel rows. Bottom and littoral forms, occasionally met with in the plankton. Figures of typical species, Fig. 181.

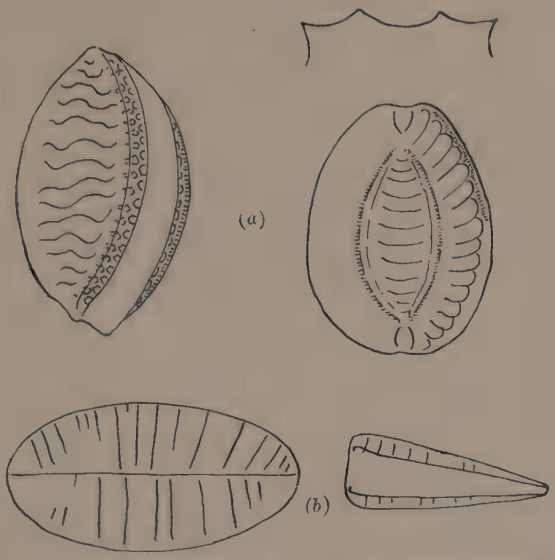


FIG. 180.—(*a*) *Surirella fastuosa* Ehr.; (*b*) *Surirella gemma* Ehr., Plymouth (M. V. L.).

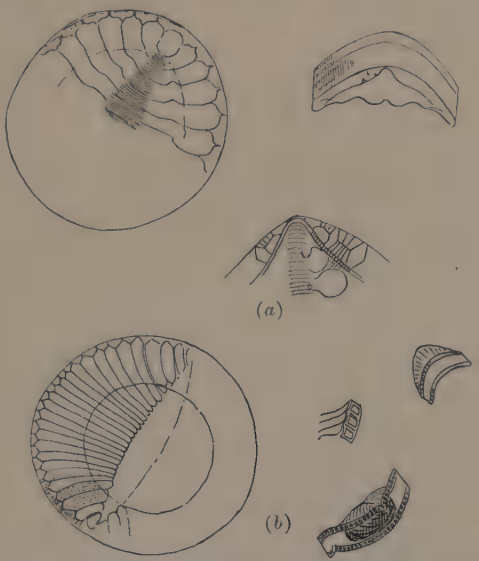


FIG. 181.—(*a*) *Campylodiscus simulans* Greg.; (*b*) *Campylodiscus decorus* Bréb., Plymouth (M. V. L.).

APPENDIX.

Methods of Collecting and Examining Planktonic Marine Diatoms.

Littoral diatoms may be easily collected from rock-pools and from sand at low tide. For truly planktonic forms a tow-net is used, or samples of water taken in bottles and subsequently centrifuged.

A tow-net made of very fine silk (180 strands to the inch) will catch most of the larger species, the net being rinsed into a glass jar and the sample examined alive under the microscope. For centrifuging water taken in a bottle any kind of centrifuge will do, a small hand one serving the purpose quite well. The tubes used should be drawn out into points so that, after centrifuging, the surface contents may be emptied out, the remains which are in the point being pipetted on to a microscope slide and examined alive. Centrifuging for 5 or 10 minutes is quite sufficient to bring down most of the sample.

By far the best way is to examine and identify the diatoms alive, when their chromatophores can be seen in the natural state. If preservation is necessary the samples can be preserved in 5% formalin, or in Fleming's solution (by adding 10 c.c. of strong Fleming solution—15 vols. 1% chromic acid, 4 vols. 2% osmic acid, 1 vol. glacial acetic acid—to 250 c.c. of the sample).

Special water-bottles are used for procuring specimens of sea-water at various depths.

Cultures of diatoms may be made by the method used by Dr. Allen of the Plymouth Laboratory (Allen and Nelson, 1910; Allen, 1914), details of which may be found in the papers quoted. To make rough cultures separate diatoms may be picked out with a pipette under a low magnifying lens and placed in Petri dishes or small flasks of filtered water in positions out of the direct sunlight.

For microscopic preparations the diatoms may be mounted in formalin in a cell made of brown cement and ringed with the same. For dry microscopic mounts the various general works on freshwater and bottom diatoms must be consulted.

LIST OF WORKS REFERRED TO.

AGARDH, C. A. 1824. Systema Algarum. Lund.

——— 1830–32. Conspectus criticus Diatomacearum. Lund.

ALLEN, E. J. 1914. On the Culture of the Plankton Diatom *Thalassiosira gravida* in Artificial Sea-water.
Journ. Mar. Biol. Assoc., N.S. X, No. 3.

——— 1919. A Contribution to the Quantitative Study of Plankton.
Ibid. XII, No. 1.

——— and NELSON, E. W. 1910. On the Artificial Culture of Marine Plankton Organisms.
Ibid. VIII, No. 5.

ALLEN, W. E. 1921*a*. Preliminary Statistical Studies of Marine Phytoplankton of the San Diego Region, California. Spec. Pub. of Bernice P. Bishop Museum, No. 7.

——— 1921*b*. Studies on Catches of Marine Phytoplankton made by aid of the Kofoid Bucket.
Ecology, IV, No. 1.

——— 1922. Quantitative Studies on Marine Phytoplankton at La Jolla in 1919.
Univ. Cal. Pub. Zoology, XII, No. 3.

——— 1923*a*. Observations on Surface Distribution of Marine Diatoms of Lower California in 1921.
Proc. Cal. Acad. Sci. XII, No. 23.

——— 1923*b*. Studies on Marine Diatoms and Dinoflagellata caught by aid of the Kofoid Bucket in 1922.
Univ. Cal. Pub. Zoology, XXII, No. 11.

——— 1924*a*. Observations on Surface Distribution of Marine Diatoms of Lower California in 1922.
Ecology, V, No. 4.

——— 1924*b*. Surface Catches of Marine Diatoms and Dinoflagellates made by U.S.S. Pioneer between San Diego and Seattle in 1923.
Univ. Cal. Pub. Zoology, XXVI, No. 12.

——— and LEWIS, R. 1927. Surface Catches of Marine Diatoms and Dinoflagellates from Pacific High Seas in 1925 and 1926.
Bull. Scripps Inst. Oceanogr., La Jolla, California, Tech. Ser. I, No. 12.

ALLEN, W. E. 1928*a*. Quantitative Studies on Inshore Marine Diatoms and Dinoflagellates collected in Southern California. *Ibid.* Tech. Ser., I, No. 15.

——— 1928*b*. Review of Five Years of Studies on Phytoplankton at Southern California Piers, 1920–1924 inclusive. *Ibid.* Tech. Ser., I, No. 16.

APSTEIN, C. 1901. Plankton in Rügischen Gewässern, Kiel. Wiss. Meeres. Unters. Abt. Kiel, N.F. V.

ATKINS, W. R. G. 1923. The Phosphate Content of Fresh and Salt Waters in its Relationship to the Growth of the Algal Plankton. Journ. Mar. Biol. Assoc., N.S. XIII, No. 1.

——— 1925. Seasonal Changes in the Phosphate Content of Sea Water in Relation to the Growth of the Algal Plankton during 1923 and 1924.
Ibid. XIII, No. 3.

——— 1926. The Phosphate Content of Sea Water in Relation to the Growth of Algal Plankton, Part III.
Ibid. XIV, No. 2.

——— 1928. Seasonal Variation in the Phosphate and Silicate Content of Sea Water during 1926 and 1927 in Relation to the Phytoplankton Crop.
Ibid. XV, No. 1.

AURIVILLIUS, C. W. S. 1896. Das Plankton des Baltischen Meeres.
Bihang til K. Svensk. Vet.-Ak. Handl., XXI, Afd. 4, No. 8. Stockholm.

BAILEY, J. W. 1842. American Bacillariæ. Pt. II: Naviculaceæ. Pt. III: Echinella and Lacerata.
Amer. Journ. Sci. XLII–XLIII, New Haven.

——— 1850. Microscopical Observations made in South Carolina, Georgia and Florida.
Smithsonian Contr. Knowl. II, Art. 8, Washington.

——— 1854. Notes on New Species and Localities of Microscopical Organisms.
Ibid. VII.

——— 1855. New Species of Diatomaceæ.
Quart. Journ. Micro. Sci. III. London.

——— 1856. On Microscopic Forms in the Sea of Kamschatka.
Amer. Journ. Sci. and Arts, ser. 2, XXII. New Haven.

BAILEY, L. W. 1862. Notes on New Species of Microscopical Organisms, chiefly from the Para River, South America.
Boston Journ. Nat. Hist. VII.

BERGON, P. 1902. Developpement chez certaines Diatomées pélagiques.
Le Micrographe préparateur, X.

——— 1903*a*. Études sur la flore diatomique du Bassin d'Arcachon et des parages de l'Atlantique voisins de cette station.
Bull. Soc. d'Arcachon Stat. Biol. VI.

——— 1903*b*. Note sur un mode de Sporulation observée chez le *Biddulphia mobiliensis* Bail.
Ibid. VI.

——— 1904. Nouvelles recherches sur un mode de Sporulation observée chez le *Biddulphia mobiliensis* Bail.
Ibid. VI.

——— 1905. Note sur certaines particularités remarquables observées chez quelques espèces de Diatomées du Bassin d'Arcachon.
Le Micrographe préparateur, XIII, No. 6.

——— 1907. Les processus de division, de rajeunissement de la cellule et de sporulation chez le *Biddulphia mobiliensis* Bailey.
Bull. Soc. Bot. France, LIV. Paris.

BIGELOW, H. B. 1926. Plankton of the Offshore Waters of the Gulf of Maine.
Bull. Bur. Fish. Washington, XL, Pt. 2 (Document No. 968), 1924.

BOYER, P. S. 1900. The Biddulphioid Forms of North American Diatomaceæ.
Proc. Acad. Nat. Sci., Philadelphia, L.

——— 1926, 1927. Synopsis of the North American Diatomaceæ. Part I: Coscinodiscatæ, Rhizosolenatæ, Biddulphiatæ. Part II: Naviculatæ, Surirellatæ.
Ibid. LXXVIII, LXXIX, Supp.

BORY DE SAINT VINCENT. 1822. Dict. Class. Hist. Nat.

BRÉBISSON, A. DE. 1857. Description de quelques nouvelles Diatomées observées dans le Guano de Pérou, formant le genre Spatangidium.
Bull. de la Soc. Linn. de Normandie, II.

BREEMEN, P. J. VAN. 1905. Plankton van Nordsee en Zuider-Zee.
Tijdschr. Ned. Dierk. Ver., Helder.

——— 1906. Bemerkungen ueber einige Planktonformen.
Verhandl. uit het Rijksinstituut voor het Oenderzoek der Zee. I Deel V.

BRIGHTWELL, T. 1853. On the Genus *Triceratium*, with description and figures of the Species.
Quart. Journ. Micro. Sci. I, London.

——— 1856. On the Filamentous Long-horned Diatomaceæ.
Ibid. IV.

——— 1858*a*. Remarks on the Genus *Rhizosolenia* of Ehrenberg.
Ibid. VI.

——— 1858*b*. Further observations on the Genera *Triceratium* and *Chætoceras*.
Ibid. VI.

——— 1859–60. On Some of the Rarer or Undescribed Species of Diatomaceæ, Parts I, II.
Ibid. VII, VIII.

BROCH, H. 1908. Planktonstudien an der Mündung der Ostsee im Juli 1907.
Svensk. hydrog-biolog. Komm. Skrifter, IV. Göteborg.

——— 1907. Phytoplankton Tables. Damas and Koefoed. Le Plankton de la Mer du Grønland. Duc d'Orleans: Croisière océanographique accomplie à bord de la Belgica, dans la Mer du Grønland, 1905.
Brussels.

BUFFHAM, T. H. 1885. Newly Observed Phenomena in the Conjugation of the Diatom *Rhabdonema arcuatum*.
J. Quekett Micr. Club, 2 ser., II.

Bulletin des Résultats acquis pendant les courses périodiques, publiés par le Bureau du Conseil International pour l'exploration de la Mer. Année 1902–3, 1903–4.
Copenhagen.

Bulletin Planktonique. Conseil Permanent International pour l'Exploration de la Mer. 1912–14.

BUSCH, W. 1916. Ueber das Plankton der Kieler Föhrde im Jahre 1912–13. I Teil.
Wiss. Meeresunters. XVIII, Kiel, 1916–20.

BYGRAVE, W. 1911. Report on the Plankton of the English Channel in 1906.
Int. Inv. Mar. Biol. Assoc., Rep. III, 1906–8.

CASTRACANE, F. 1873*a*. Contribuzione alla florula delle Diatomee del Mediterraneo, etc.
Atti Accad. Pont. Nuov. Linc. XXVIII. Rome.

——— 1873*b*. Diatomée del litorale dell'Istria e della Dalmazia.
Ibid. XXVIII.

Castracane, F. 1880. Nuova contribuzione alla florula della Diatomei del Mediterraneo.
Ibid. XXXV.

——— 1886. Report on the Diatomaceæ collected by H.M.S. "Challenger" during the years 1873–76.
Report of the "Challenger" Exp. Botany, II.

——— 1898. Una Raccolta di Diatomée alla imboccatura del porto-canale di Fano.
Atti Accad. Pont. Nuov. Linc. LI.

Chatton, E. 1920. Les Péridiniens parasites.
Arch. Zool., Paris, t. 59.

Cleve, P. T. 1864. Diatomaceer från Spetzsbergen.
Oefvers. K. Vet.-Ak. Forhandl. No. 10. Stockholm.

——— 1873*a*. Examination of Diatoms found on the Surface of the Sea of Java.
Bih. t. K. Svensk. Vet.-Ak. Handl. I, No. 11. Stockholm.

——— 1873*b*. On Diatoms from the Arctic Sea.
Ibid. No. 13.

——— 1878. Diatoms from the West Indian Archipelago.
Ibid. V, No. 8.

——— 1881. On Some New and Little-known Diatoms.
K. Svensk. Vet.-Ak. Handl. XVIII, No. 5.

——— 1883. Diatoms collected during the Expedition of the "Vega."
"Vega" Exp. Vetensk. Iaktt. Bd. III. Stockholm.

——— 1889. Pelagiske Diatomeer från Kattegat. Det Videnskabelige Udbytte af Kanonbaaden "Hauch's" Togter i de Danske Have, Hft. I.
Copenhagen.

——— 1891. The Diatoms of Finland.
Acta Soc. pro fauna et flora fennica, VIII, No. 2. Helsingfors.

——— 1894. Planktonuntersökningar. Cilioflagellater og Diatomaceer.
Bih. t. k. Svenska Vet.-Ak. Handl., XX, Afd. 3, No. 2. Stockholm.

——— 1894–95. Synopsis of the Naviculoid Diatoms.
K. Svensk. Vet. Ak. Handl. XXVI, No. 2 (XXVII, No. 3).

——— 1896*a*. Diatoms from Baffin's Bay and Davis Strait.
Bih. t. K. Svensk. Vet.-Ak. Handl. XXII, Afd. 3, No. 4.

——— 1896*b*. Planktonuntersökningar. Vegetabilisk Plankton.
Ibid. XXII, Afd. 3, No. 5.

CLEVE, P. T. 1897*a* A Treatise on the Phytoplankton of the Northern Atlantic and its Tributaries.
Upsala.

——— 1897*b*. Report on the Phytoplankton collected on the Expedition of H.M.S. "Research," 1896.
Fifteenth Ann. Rep. Fish. Board for Scotland, Pt. III. Edinburgh.

——— 1897*c*. Karaktäristik af Atlantiska Oceans vatten pa grun af den mikroorganismer.
Oefvers K. Vet.-Ak. Forhandl. 1897, No. 3.

——— 1897*d*. Microscopic Marine Organisms in the Service of Hydrography.
Nature, LV, No. 1413, and Journ. Mar. Biol. Assoc., N.S. IV, No. 4.

——— 1899*a*. Plankton Collected by the Swedish Expedition to Spitzbergen in 1898.
K. Svensk. Vet.-Ak. Handl. XXXII, No. 3. Stockholm.

——— 1899*b*. Plankton Researches in 1897.
Ibid. XXXII, No. 7.

——— 1900*a*. Notes on Some Atlantic Plankton Organisms.
Ibid. XXXIV, No. 1.

——— 1900*b*. The Plankton of the North Sea, the English Channel and the Skaggerak in 1898 and 1899.
K. Svensk Vet.-Ak. Handl. XXXIV, No. 2. Stockholm.

——— 1900*c*. Plankton from the Southern Atlantic and Southern Indian Ocean.
Oefers. K. Vet.-Ak. Forhandl., No. 8.

——— 1900*d*. Plankton from the Red Sea.
Ibid. No. 9.

——— 1900*e*. Report on the Plankton collected by the Swedish Expedition to Greenland in 1899.
K. Svensk. Vet.-Ak. Handl. XXXIV, No. 3. Stockholm.

——— 1901*a*. The Seasonal Distribution of Atlantic Plankton Organisms.
Kgl. Vet. och Vett. Samh. Hand. XVII. Göteborg.

——— 1901*b*. Plankton from the Indian Ocean and the Malay Archipelago.
K. Svensk. Vet.-Ak. Handl. XXXIV. Stockholm.

——— 1902*a*. Additional Notes on the Seasonal Distribution of Atlantic Plankton Organisms.
Kgl. Vet. och Vett. Samh. Hand. XVIII. Göteborg.

Cleve, P. T. 1902*b*. Plankton Researches in 1901 and 1902.
K. Svensk. Vet.-Ak. Handl. XXXVI, No. 8.

——— 1903. Report on Plankton Collected by Mr. Thorold Wulf during a Voyage to and from Bombay.
Arkiv f. Zoologi, I. Stockholm.

——— and Grunow, A. 1880. Beiträge zur Kenntniss der Arktischen Diatomeen.
K. Svensk. Vet.-Ak. Handl. XVII, No. 2.

——— and Mereschkowsky, C. 1902. Notes on some Recent Publications concerning Diatoms.
Ann. and Mag. Nat. Hist., ser. 7, X.

——— and Möller, J. D. 1877–82. Diatoms, Parts I–VI.
Upsala.

Cleve-Euler, A. 1915. New Contributions to the Diatomaceous Flora of Finland.
Ark. f. Bot. XIV, No. 9.

Crawshay, L. R. 1914. On the Distribution of the Microplankton. Report on the work carried out by the S.S. "Scotia," 1913.
Ice Observation, Meteorology and Oceanography in the North Atlantic Ocean. London.

Daday, E. 1887. Monographie der Familie der Tintinnoideen.
Mitt. aus d. Zool. Stat. zu Neapel, VII.

De Toni, G. B. 1891. Sylloge Algarum omnium hucusque cognitarum. II. Bacillariæ. Sect. 1–3.
Patavia.

——— 1916. Alcune considerazione sulla flora marina.
Nova Notarisia, XXVII.

——— and Forti, A. 1916. Analisi microscopica di Alcuni saggi di fitoplancton raccolti dalla R.N. "Liguria."
Memorie del R. Istituto Veneto di Scienze, Lettere ed Arti, XXIX, No. 1.

Dillwyn, L. W. 1809. British Confervæ ; or Coloured Figures and Descriptions of the British Plants referred by Botanists to the Genus Conferva.
London.

Ehrenberg, C. G. 1839. Ueber die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen.
Abhandl. d. k. Ak. d. Wissensch. zu Berlin aus dem Jahre 1838. Berlin.

EHRENBERG, C. G. 1841. Ueber noch jetzt zahlreich lebende Tierarten der Kreidebildung und der Organismus der Polythalmien.
Ibid. 1839–40.

——— 1843. Neue Beobachtung über den sichtlichen Einfluss der Mikroskopischen Meeres-organismen auf den Boden des Elbeltes bis oberhalt Hamburg.
Monatsber. d. Berliner Akad. d. Wiss. Berlin.

——— 1844. Einige vorläufige Resultate seiner Untersuchungen der ihm von der Südpolreise des Capitain Ross, sowie von den Herren Schayer und Darwin zugekommenen Materialien. . . .
Ibid.

——— 1845. Neue Untersuchungen über das kleinste Leben als geologische Moment.
Ibid.

——— 1854. Microgeologie.
Leipzig.

——— 1873. Microgeologische Studien über das kleinste Leben der Meerestiefgründe aller Zonen und dessen geologischen Einfluss.
Abhandl. d. k. Ak. d. Wissensch. zu Berlin, 1872. Berlin.

ENGLER, A. 1883. Ueber die pelagischen Diatomeen der Ostsee.
Ber. d. Deutsch. Bot. Gesellsch. I. Berlin.

FAMINTZIN, A. 1889. Beitrag zur Symbiose von Algen und Tieren.
Mém. Acad. Sci. de St. Petersburgh, vii^{e} sér., t. 36. St. Petersburgh.

FISH, C. J. 1925. Seasonal Distribution of the Plankton of the Woods Hole Region.
Bull. Bur. of Fish. Washington, XLI, Doc. 975.

FORTI, A. 1906. Alcune osservazione sul "Mare sporco" ed in particulare sul fenomeno avvento nel 1905.
Nuova Giornale Bot. It. 1906.

——— 1912. Contribuzioni Diatomologiche, XII.
Atti del Reale Ist. Veneto di Sci. etc. LXXI, pt. 2.

——— 1913. Primi Studi per un explorazione limnobiologica dell'oriente.
Nuova Notarisia, XXIV. Padua.

——— 1914. "Algæ" ex Sommier et Caruana-Galto.
Flora Melitensis Nova. Firenze.

FORTI, A. 1922. Ricerche su la flora pelagica (fitoplankton) di Quarto dei Mille (Mare Ligure).
R. Com. talass. It. Lab. Mar. di quarto dei Mille Presso Genova, Mem. XCVII.

——— and ISSEL, R. 1924. Di Altri elementi nuovi osservoli nel microplancton del mare Adriatico di Rovigno.
Nuova Notarisia, XXXIV, 1923. Padua.

FRITZ, C. 1921*a*. Plankton Diatoms, their Distribution and Bathymetric Range in St. Andrews Waters.
Contr. to Canadian Biology, 1918–20 (21). Ottawa.

——— 1921*b*. Experimental Cultures of Diatoms occurring near St. Andrews, N.B.
Ibid. 1918–20 (21).

GEITLER, L. 1928. Copulation und Geschlechtsverteilung bei einer *Nitzschia* Art.
Arch. f. Protistenk. LXI, Heft 3.

GOUGH, L. F. 1905. Report on the Plankton of the English Channel in 1903.
Mar. Biol. Assoc. Internat. Invest. Rept. I.

——— 1907. Report on the Plankton of the English Channel in 1904 and 1905.
Ibid. II.

GRAN, H. H. 1897*a*. Protophyta: Diatomaceæ, Silicoflagellata and Cilioflagellata.
Den Norske Nordhavs Expedition 1876–78, Heft 24.

——— 1897*b*. Bacillariaceæ vom kleinen Karajakfjord.
Bibliotheca botanica, Heft 42, Stuttgart.

——— 1900*a*. Hydrographic-biological Studies of the North Atlantic Ocean and the Coast of Nordland.
Rep. on Norweg. Fish. and Mar. Inv. I, No. 5. Christiania.

——— 1900*b*. Bemerkungen über einige Plankton diatomeen.
Nyt Mag. Naturvidensk. XXXVIII. Christiania.

——— 1900*c*. Diatomaceæ from the Ice Floes and Plankton of the Arctic Ocean.
The Norwegian North Polar Expedition, 1893. Scientific Results edited by Fridthjof Nansen, IV, No. 11. Christiania.

GRAN, H. H. 1902. Das Plankton des Norvegischen Nordmeeres von biologischen und hydrographischen Gesichtspunkten behandelt.
Rep. on Mar. and Fish. Inv. II, No. 5. Bergen.

——— 1904. Die Diatomeen der Arktischen Meere. I. Teil: Die Diatomeen des Planktons.
Fauna Arctica, III, Lief 3. Jena.

——— 1905. Nordisches Plankton, XIX, Diatomeen.
Kiel und Leipzig.

——— 1912. Pelagic Plant Life. Chapter VI of 'The Depths of the Ocean,' by Murray, Sir J., and Hjort, J. London.

——— 1915. The Plankton Production of the North European Waters in the Spring of 1911.
Bull. Plank., p. l'année 1912. Copenhagen.

——— 1927. The Production of Plankton in the Coastal Waters off Bergen, March and April, 1922.
Rep. Norweg. Fish. and Mar. Inv. III, No. 8.

——— and GAARDER, T. 1927. Investigations of the Production of Plankton in the Oslo Fjord.
Rapp. et. Procès-verb. d. réunions Cons. Perm. Int. p. l'Expl. de la Mer. XLII.

——— and RUUD, B. 1926. Untersuchungen über die im Meereswasser gelösten organischen Stoffe und ihr verhältnis zur Planktonproduction.
Avhand. utgitt av Det Norske Vid. Ak. i Oslo. I. Matem. Natur. Kl. 1926, No. 6.

——— 1927. Ueber die Plankton production im Hurdals-See.
Ibid. No. 1.

——— 1928. Quantitative Plankton Investigations Carried out during the Expedition with the "Michael Sars," July–September, 1924.
Cons. Perm. p. l'Expl. de la Mer.

——— BRAARUD, T., and FÖYN, B. 1928. Biologische Untersuchungen in einigen Seen des Östlichen Norwegen August–September, 1927.
Norske Vid. Ak. Oslo, I, Math.-Naturw. Kl. No. 2.

——— and YENDO, K. 1914. Japanese Diatoms: I. On Chætoceras; II. On Stephanopyxis.
Vid. Skrift. I. Nat. Natur. Klasse 1913, No. 8. Christiania.

GRAY, S. F. 1832. Arrang. Brit. Plants, I, 294.

GREGORY, W. M. D. 1857. On New Forms of Marine Diatomaceæ found in the Firth of Clyde and in Loch Fyne. Trans. R. Soc. Edinburgh, XXI. Edinburgh.

GREVILLE, R. K. 1833. The Diatomaceæ in Hooker's 'British Flora.'

——— 1859. Descriptions of Diatomaceæ observed in Californian Guano.
Quart. Journ. Micr. Sci. VII. London.

——— 1865. Descriptions of New Genera and Species of Diatoms from Hongkong.
Ann. Nat. Hist. ser. 3, XVI. London.

——— 1866. Descriptions of New and Rare Diatoms. Ser. XVIII–XX.
Trans. Micr. Sci. London, XIV.

GRUNOW, A. 1862. Die Österreichischen Diatomeen.
Verhandl. d. K. K. Zool. Bot. Gesellsch. XII. Vienna.

——— 1863. Ueber einiger neue und ungenügend bekannte Arten und Gattungen von Diatomaceen.
Ibid. XIII.

——— 1867. Nachträgliche Bemerkungen über die von Herrn Lindig gesammelten Diatomeen von Honduras.
Hedwigia, VI. Dresden.

——— 1868. Reise seiner Majestät Fregatte Novara um die Erde.
Bot. Teil. I, Algen. Vienna.

——— 1884. Die Diatomeen von Franz-Josefs-Land.
Denkschr. d. Kais. Ak. d. Wissensch. Math.-Naturw. Klasse, XLVIII. Vienna.

HARVEY, H. W. 1926. Nitrate in the Sea.
Journ. Mar. Biol. Assoc., N.S. XIV, No. 1.

——— 1928. Nitrate in the Sea, II.
Ibid. XV, No. 1.

HASSAL, A. H. 1845. History of the British Freshwater Algæ.

HEIBERG, A. C. 1863. Conspectus criticus Diatomacearum Danicarum. Copenhagen.

HENSEN, V. 1887. Ueber die Bestimmung des Plankton. 5. Bericht der Kommission zur wissenschaftlichen Untersuchung der deutschen Meere bei Kiel für die Jahre 1882–86. Kiel.

HERDMAN, W. A. 1913, '14, '18, '20, '22. Spolia Runiana, I to V. Journ. Linn. Soc. Botany, XXXII to XLVI.

——— SCOTT, A., and LEWIS, H. M. 1914. An Intensive Study of the Marine Plankton around the South End of the Isle of Man, Part VII.
Proc. and Trans. Liverpool Biol. Soc. XXVIII, Session 1913–14 (1914).

IKARI, J. 1923. On the Nuclear and Cell Division of a Plankton Diatom, *Coscinodiscus sub-bulliens* Jörgensen.
Bot. Mag. No. 37. Tokyo.

JÖRGENSEN, E. 1900. Protophyten und Protozoen im Plankton aus der Norwegischen West Kuste.
Bergens Mus. Aarbog for 1899, No. 6. Bergen.

——— 1901. Protistplankton aus dem Nordmeere in den Jahren 1897–1900.
Ibid. for 1900, No. 6.

——— 1905*a*. Diatoms in Bottom Samples from Lofoten and Westeraalen.
Bergens Museums Skrift. VII.

——— 1905*b*. Protistplankton of Northern Norwegian Fjords.
Ibid.

——— 1912 or 1913. Bericht über die von der schwedisches hydrographisch-biologischen Kommission in dem schwedischen Gewässern in den Jahren 1909–10 eingesammelten Planktonproben.

JORGENSEN, O. M. 1918. Plankton of the Supply Tanks of the Dove Marine Laboratory.
Rep. Dove Mar. Lab. Cullercoats, Northumberland.

KARSTEN, G. 1898. Ueber die Formänderungen von *Skeletonema costatum* (Grev.) Grun. und ihre Abhängigkeit von äusseren Faktoren.
Wiss. Meeres. Abt. Kiel, III. Kiel.

——— 1899. Die Diatomeen der Kieler Bucht.
Ibid. IV. Kiel.

——— 1904. Die Sogenannten "Microsporen" der Planktondiatomeen und ihre weitere Entwicklung beobachtet an *Corethron valdiviæ* n. sp.
Ber. d. Deutsch. Bot. Ges. XXII. Berlin.

KARSTEN, G. 1905. Das Phytoplankton des Antarktischen Meeres nach dem Material der deutschen Tief-see Expedition. Wiss. Ergebn. d. deutsch. Tief-see Exp. auf dem Dampfer "Valdivia" II. Jena.

——— 1906. Das Phytoplankton des Atlantischen Oceans, etc. *Ibid*, II, 2.

——— 1907. Das Indische Phytoplankton. *Ibid*, II, 3.

——— 1924. Ueber Diatomeen, ihre Fortpflanzung und verwandtschaftlichen Beziehungen. Int. Rev. d. ges. Hyd. u. Hydrog. XII. Hft. 1–2.

——— 1928. Bacillariophyta (Diatomeæ) in Engler und Prantl, Die Natürlichen Pflanzenfamilien. Zweite Auflage, II.

KÜTZING, F. T. 1844. Die Kieselschaligen Bacillarien oder Diatomeen. Nordhausen.

LAUDER, H. S. 1864. (*a*) On New Diatoms. (*b*) Remarks on the Marine Diatomaceæ Found at Hong Kong, with Descriptions of New Species, with notes by J. Ralfs. Trans. Micr. Soc. N.S. XII. London.

LEBOUR, M. V. 1917. The Microplankton of Plymouth Sound from the Region beyond the Breakwater. Journ. Mar. Biol. Assoc. N.S. XI, 2.

LEMMERMANN, E. 1898. Der Grosse Waterneverstorfer Binnensee. Eine biologische Studie. Forschungsberichte aus der biologischen Station zu Plön, Teil 6, Abt. II.

——— 1899. Ergebnisse einer Reise nach dem Pacific (H. Schauinsland, 1896–97). Plankton-Algen. Abh. d. Naturh. Ver. Bremens, XVI. Bremen.

——— 1905. Das Phytoplankton des Meeres, III Beitrag. Befefte z. bot. Centr.-bl., Abt. II, XIX.

LEWIS, R. 1927. Surface Catches of Marine Diatoms and Dinoflagellates off the Coast of Oregon by U.S.S. "Guide" in 1924. Bull. Scripps Inst. Oceanogr., La Jolla, California, Tech. Ser. 1, No. 11.

LLOYD, B. 1925. Marine Phytoplankton of the Welsh Coasts, with Special Reference to the Vicinity of Aberystwyth. Journ. of Ecology, XIII, No. 1.

Lloyd, B. 1926. Character and Conditions of Life of Marine Phytoplankton.
Ibid. XIV, No. 1.

Lohmann, H. 1902. Neue Untersuchungen über den Reichthum des Meeres an Plankton.
Wiss. Meeres, N.F. VII. Kiel u. Leipzig.

——— 1908. Untersuchungen zur Feststellung des vollständigen Gehalts des Meeres an Plankton.
Ibid. X.

——— 1917. Die Bevölkerung des Ozeans mit Plankton nach den Ergebnissen der Zentrifugenfänge während der Ausreise der "Deutschland," 1911. Zugleich ein Beitrag zur Biologie des Atlantischen Ozeans, Teil I–II.
Arch. f. Biontologie herausg. v. d. Gesellsch. naturforsch. Freunde zu Berlin, IV, Hft. 3.

Lönnberg, E. 1900. Contributions to the Biology of the Caspian Sea.
Öfvers K. Svensk. Vet.-Ak. Forhandl. No. 1. Stockholm.

Lyngbye, H. B. 1819. Tentamen Hydrophytologiæ Danicæ. Copenhagen.

Mangin, L. 1908. Observations sur les Diatomées.
Ann. Sci. Nat. Bot. 9^{e} sér. VIII. Paris.

——— 1910. Sur quelques algues nouvelles ou peu connues du Phytoplankton de l'Atlantique.
Bull. Soc. bot. France, 57. Paris.

——— 1911. Observations sur le Phytoplankton de la côte occidentale d'Afrique.
Soc. Linn de Bordeaux, p. 335.

——— 1912. Phytoplancton de la croisière du René dans l'Atlantique.
Ann. Inst. Océanogr. IV. Paris.

——— 1913. Sur la flore planctonique de la rade St. Vaast-la-Hougue 1908–1912.
Nouv. Archiv. Muséum d'Hist. Nat. 5° ser., 5.

——— 1914. Sur le polymorphisme de certaines Diatomées antarctiques.
C.R. Acad. Sci. 159.

——— 1915. Phytoplancton de l'Antarctique. Deuxième Expéd. Antarct. franç. 1908–1910. Jean Charcot, Paris.

MANGIN, L. 1917. Sur le *Chætoceros criophilus*, espèce caractéristique des mers antarctiques.
C.R. Acad. Sci. 164, 1917, pp. 704 et 770.

——— 1919. Sur les Chætoceros du groupe *Peruvianus* Bgtw. Bull. Mus. Nat. d'Hist. Nat. 25, pp. 305 et 411.

——— 1922. Phytoplancton antarctique. Expédition antarctique de la "Scotia," 1902–1904. Dirigée par Dr. William S. Bruce, LL.D.
Mém. de l'Acad. des Sci. de l'Inst. de France, 17.

MARSHALL, S. M., and ORR, A. P. 1927. The Relation of the Plankton to Some Chemical and Physical Factors in the Clyde Sea Area.
Journ. Mar. Biol. Assoc. N.S. XIV, No. 4.

——— 1928. The Photosynthesis of Diatom Cultures in the Sea.
Ibid. XV, No. 1.

MATTHEWS, D. 1916. On the Amount of Phosphoric Acid in the Sea-water off Plymouth Sound.
Ibid. XI, 1.

——— 1917. On the Amount of Phosphoric Acid in the Sea-water off Plymouth Sound, II.
Ibid. XI, 2.

MERESCHKOWSKY, C. 1902. Notes sur quelques Diatomées de la mer noir, suivies d'une liste des formes observées dans cette mer.
Journ. de Bot. 16^{e} ann. Paris.

MEUNIER, A. 1910. Microplancton des Mers de Barents et de Kara.
Duc d'Orléans, Campagne Arctique de 1907. Brussels.

——— 1913. Microplankton de la Mer Flamande. I^{re} Partie : Le genre *Chætoceros* Ehrg.
Mem. Mus. R. Hist. Nat. Belgique, 3. Brussels.

——— 1915. *Ibid.* II^{e} Partie.

MIELCK, W. 1911. Quantitative Untersuchungen an dem Plankton der deutschen Nordsee. Terminfahrten im Februar und Mai.
Wiss. Meeresunt. Kiel, N.F. 1906, XIII.

MILLS, F. W., and PHILIP, R. H. 1901. The Diatomaceæ of the Hull District.
Trans. Hull Sci. and Field Nat. Club.

MIQUEL, P. 1894. Du Noyau chez les Diatomées.
Le Diatomiste, II, No. 18. Paris.

MÜLLER, O. 1895. Ueber Achsen, Orientierung—und Symmetrie—Ebenen bei den Bacillariaceen.
Ber. d. deutsch. Bot. Gesellsch. XIII. Berlin.

——— 1898. Kammern und Poren in der Zellwand der Bacillariaceen.
Ibid. XVI, Berlin.

MURRAY, G. 1896. On the Reproduction of some Marine Diatoms.
Proc. R. Soc. Edinburgh, XXI. Edinburgh.

OESTRUP, E. 1895. Marine Diatomeer fra Oestgrønland.
Medd. om Grønland, XVIII. Copenhagen.

OKAMURA, K. 1907. Some *Chætoceras* and *Peragallia* of Japan.
Bot. Mag. XXI. Tokyo.

——— 1911. Some Littoral Diatoms of Japan.
Rep. Imp. Fish. Inst. VII. Tokyo.

OLTMANN, F. 1922. Algen. II—Aufl. I.

OSTENFELD, C. H. 1899. Plankton in 1898.
Iagttagelser over Overfladevandets Temperatur, Saltholdighed og Plankton paa islandske og grönlandske Skibsrouter i 1898, udgivne af Martin Knudsen og C. Ostenfeld.

——— 1900. Plankton in 1899.
Ibid. for 1899.

——— 1901*a*. Jagttagelser over Plankton-Diatomeer.
Nyt Mag. f. Naturvid. XXXIX, H. 4. Christiania.

——— 1901*b*. Phytoplankton fra det Kaspide Hav.
Vidensk. Medd. Naturh. Foren. pp. 129–139. Copenhagen.

——— 1902. Marine Plankton Diatoms. Johs. Schmidt : Flora of Koh-Chang. Part 7.
(Reprinted from Botanisk. Tidsskrift. XXV.) Copenhagen.

——— 1903. Phytoplankton from the Sea around the Faroes. Botany of the Faroes, II. Copenhagen.

——— 1908*a*. The Phytoplankton of the Aral Sea and its Affluents.
Wiss. Ergeb. d. Aralsee-Exp. Lief VII. St. Petersburg.

——— 1908*b*. On the Immigration of *Biddulphia sinensis* Grev. and its occurrence in the North Sea during 1903–1907.
Medd. Komm. Hav. S. Plankton, I, No. 6. Copenhagen.

——— 1910. Marine Plankton from the East Greenland Sea. I : List of Diatoms and Flagellates.
Med. om Grønland, XLIII. Copenhagen.

Ostenfeld, C. H. 1912. A Revision of the Marine Species of *Chætoceras* Ehrbg., Sect. Simplicia Ostf. With 24 figures in the text. Medd. Komm. Hav. S. Plankton, 1, No. 10. Copenhagen.

——— 1913*a*. De Danske Farvands Plankton i Aarene 1898–1901. Phytoplankton og Protozoa. Copenhagen.

——— 1913*b*. Bacillariales (Diatoms) Copenhagen. Bull. Trimes. etc., Résumé Plankt., 3e part.

——— 1915. A List of Phytoplankton from the Boeton Strait, Celebes. Dansk. bot. Arkiv. II, No. 4, Note. Copenhagen.

——— 1916. Catalogue des espèces de plantes et d'animaux observées dans le plankton recueilli pendant les Expéditions depuis le mois de Juillet 1908 jusqu' au mois de Décembre 1911. Copenhagen. Cons. Perm. int. p. l'Expl. de la Mer. Pub. de Circ. No. 70.

——— and Paulsen, O. 1904. Planktonpröver fra Nord-Atlanterhavet (c. 58°–60° N. Br.), samlede i 1899 af Dr. K. J. V. Steenstrup. Medd. om Grønland, XXVI. Copenhagen.

——— 1911. Marine Plankton from the East Greenland Sea. IV. General Remarks on the Microplankton, Danmarks-Eksp. Grønlands Nordøstkyst, Bd. III, No. 11. Medd. Grønl. XLIII.

——— and Schmidt, H. 1901. Plankton fra det Røde Hav. og. Adenbughten (Red Sea and Gulf of Aden). Vid. Medd. fr. Naturh. Forening. Copenhagen.

Paulsen, O. 1904. Plankton Investigations in the Waters round Iceland in 1903. Medd. Komm. Hav. S. Plankton, I.

——— 1905. On some Peridineæ and Plankton-Diatoms. *Ibid.* I, No. 3.

——— 1909. Plankton Investigations in the Waters round Iceland and in the North Atlantic in 1904. *Ibid.* No. 8.

——— 1911. Marine Plankton from the East Greenland Sea. III. Peridiniales, Danmarks-Eksp. Bd. III, No. 11. Medd. Grønl. XLIII.

——— 1918. Plankton and other Biological Investigations in the Sea Around the Faroës in 1913. Medd. Komm. Hav. S. Plankton, I, No. 13.

PAVILLARD, J. 1904. Sur les auxospores des deux Diatomées pélagiques.
C.R. Acad. Sci. Paris, CXXXIX.
——— 1905. Recherches sur la flore pélagique (Phytoplankton) de l'étang de Thon.
Montpellier.
——— 1911. Observations sur les Diatomées.
Bull. Soc. bot. France 58. Paris.
——— 1912. L'Évolution periodique du Plankton végétal dans la Méditerranée Occidentale.
A.F.A.S. Congrès de Nîmes. Paris.
——— 1913. Observations sur les Diatomées, 2e série.
Bull. Soc. bot. France, 60. Paris.
——— 1914. Observations sur les Diatomées, 3e série.
Ibid. 61.
——— 1916*a*. Flagellés nouveaux épiphytes des Diatomées pélagiques.
C.R. Acad. Sci. Paris, 163.
——— 1916*b*. Recherches sur les Diatomées pélagiques du Golfe de Lion.
Trav. d. l'Inst. Bot. de Univ. de Montpellier, Mem. 5. Cette.
——— 1921. Sur la Reproduction du *Chætoceros Eibenii* Meunier.
C.R. Acad. Sci. Paris, 172.
——— 1924*a*. *Le Coscinodiscus gigas* Ehrbg. et ses congénères.
Revue Algologique, 2. Paris.
——— 1924*b*. Observations sur les Diatomées, 4e série. Le genre *Bacteriastrum*.
Bull. Soc. bot. France, 71. Paris.
——— 1925. Bacillariales. Report on the Danish Oceanographical Expedition 1908–10 to the Mediterranean and Adjacent Seas, II, Biology, J. 4.
PÉRAGALLO, H. 1884. Diatomées du midi de la France.
Bull. d'Hist. Nat. de Toulouse, XVIII. Paris.
——— 1888. Diatomées de la baie de Villefranche (Alpes-Maritimes).
Ibid. XXII.
——— 1892. Monograph de Rhizosolenia et de quelques genres voisins.
Le Diatomiste, 1. Paris.
——— 1904–5. Sur la Question des Spores des Diatomées.
Trav. d. Lab. Stat. Biol. d'Arcachon. Soc. Sci. d'Arcachon. Univ. de Bordeaux, 8th Ann.

Péragallo, H. 1907. Sur la Division cellulaire du *Biddulphia mobiliensis*.
Ibid. Ann. 10.

——— and M. 1897–1908. Diatomées marines de France et des districts maritimes voisins.
Grez-sur-Loing.

Péragallo, M. 1904. Première note sur les Diatomées marines de Monaco.
Bull. Mus. Océanogr. No. 7. Monaco.

Pritchard, A. 1861. A History of the Infusoria.
London.

Rattray, J. 1890*a*. A Revision of the Genus *Coscinodiscus* Ehrb. and some Allied Genera.
Proc. R. Soc. Edinburgh, XVI.

——— 1890*b*. A Revision of the Genus *Actinocyclus*.
J. Quekett Micr. Club, II, No. 27. London.

Roper, F. C. S. 1858. Notes on Some new Species and Varieties of British Marine Diatomaceæ.
Quart. Journ. Micr. Sci. VI. London.

——— 1859. On the Genus *Biddulphia* and its Affinities.
Trans. Micr. Soc. N.S. VII. London.

Schiller, J. 1909. Ein neuer fall von Mikrosporenbildung bei *Chætoceros Lorenzianum* Grün.
Ber. d. deutsch. Bot. Gesellsch. XXVII. Berlin.

——— 1912. Bericht über die botanischen Untersuchungen und deren vorläufige Ergebnisse der III Kreutzing S.M. Schiff " Najade " im Sommer 1911.
Österr. bot. Zeitschr. Jahr. 1912. 72. Vienna.

Schmidt, A. 1875. Die in den Grundproben der Nordseefahrt 1872 enthaltenen Diatomeen.
Jahresber. d. Komm. z. wiss. Unters. der deutsch. Meere in Kiel f. d. Jahre 1872–73, II.

——— 1873–1904. Atlas der Diatomaceenkunde, in Verbinding mit den Herren Gründler, Grunow, Janisch, Weissflog und Witt herausgegeben.
Aschersleben.

Schmidt, J. 1901. Ueber *Richelia intracellularis*, eine neue in Planktondiatomeen lebende Alge.
Hedwigia, XL. Dresden.

SCHMIDT, P. 1923. Morphologie und Biologie des *Melosira varians* u.s.w.
Intern. Rev. d. ges. Hydrob. u. Hydrog. XI, Heft 1–2.

——— 1927*a*. Ist die scharfe Trenning zwischen zentrischen und pennate Diatomeen haltbar? (Reduction in den Mikrosporangien von *Biddulphia sinensis*.)
Ibid. XVII, Heft 5–6.

——— 1927*b*. Weiteres über die Fortpflanzung der Diatomée *Biddulphia sinensis*. Die Kernphasen.
Ibid. XVIII, Heft 5–6.

——— 1928. Sind die "Microsporen" Diatomeen gameten oder Parasiten?
Ibid. XIX, Heft 1–2.

SCHRÖDER, B. 1900*a*. Das Phytoplankton des Golfes von Neapel.
Mitt. a. d. Zool. Stat. z. Neapel, XIV. Berlin.

——— 1900*b*. Das Phytoplankton des Golfes von Neapel.
Sitzber. Zool. bot. Gesellsch. in Breslau.

——— 1906*a*. Beiträge zur Kenntnis der Phytoplanktons warmer Meere.
Viertel. Jahrschr. d. naturforsch. Ges. in Zürich. Jahrg. 51. Zürich.

——— 1906*b*. Zur Characteristik des Phytoplanktons temperierten Meere.
Ber. d. deutsch. Bot. Ges. XXIV.

——— 1908. Neue und seltener Bacillarieen aus dem Plankton der Adria.
Ibid. XXVI. Berlin.

——— 1911. Adriatisches Phytoplankton.
Sitz. Ber. d. k. Akad. d. Wiss. in Wien, Math. Naturw. Kl. CXX.

——— 1914. Ueber Planktonepibionten.
Biol. Centralbl. XXXIV. Leipzig.

SCHULTZE, M. 1858. Innere Bewegungserscheinungen bei Diatomeen der Nordsee aus den Gattungen *Coscinodiscus*, *Denticella*, *Rhizosolenia*.
Müller's Archiv, 1858. (Summary also in Quart. Journ. Micr. Sci. 7, 1859. London.)

SCHÜTT, F. 1886. Auxosporenbildung von *Rhizosolenia alata*.
Ber. d. deutsch. Bot. Gesellsch. IV. Berlin.

——— 1888. Ueber die Diatomaceengattung *Chætoceras*.
Bot. Zeit. Nos. 11–12.

Schütt, F. 1889. Ueber die Auxosporenbildung der Gattugn *Chætoceras*.
Ber. d. deutsch. Bot. Gesellsch. VII. Berlin.
——— 1893*a*. Das Pflanzenleben der Hochsee.
Kiel und Leipzig.
——— 1893*b*. Wechselbeziehungen zwischen Morphologie, Biologie, Entwicklungsgeschichte und Systematik der Diatomeen.
Ber. d. deutsch. Bot. Gesellsch. XI. Berlin.
——— 1895. Arten von *Chætoceras* und *Péragallia*. Ein Beitrag zur Hochseeflora.
Ibid. XIII.
——— 1896. Bacillariales. Engler und Prantl: Die Natürliche Pflanzenfamilien, I Teil, Abt.1*b*.
Leipzig.
——— 1900. Centrifugale und Simultane Membranverdickungen.
Jahrbücher für wissenschaftliche Botanik. XXXV. Leipzig.
Schüssnig, B. 1914. Aus der Biologie des Adriatischen Phytoplankton.
Verhandl. d. k. k. Zool. Bot. Gesell. in Wien, July, 1914.
——— 1915. Bemerkungen zu einigen Adriatischen Planktonbacillarieen.
Sitzber. Kais. Akad. d. wiss. in Wien, Math. Naturw. Kl. Abt. 1, CXXIV. Vienna.
Shadbolt, G. 1854. A Short Description of some New Forms of Diatomaceæ from Port Natal.
Trans. Micr. Soc. II. London.
Shrubsole, W. H. 1890. On a New Diatom from the Estuary of the Thames.
J. Quekett Micr. Club, Ser. 2, IV.
Sleggs, G. F. 1927. Marine Phytoplankton in the Region of La Jolla, California, during the Summer of 1924.
Bull. Scripps Inst. Oceanogr., La Jolla, California, Tech. Ser. I, No. 9.
Smith, J. E. 1808. English Botany, XXIII, XXV, XXVII. London.
Smith, W. 1853–56. Synopsis of the British Diatomaceæ, I–II. London.
Stolterfoth, H. N. D. 1879. On a New Species of the Genus *Eucampia* (*E. striata*).
J. R. Micr. Soc. II. London.

TEMPÈRE, J. A. and PÉRAGALLO, H. 1889–95. Texte et tables de la Collection des Diatomées du Monde entier. Paris.

——— 1907–15. Diatomées du Monde entier. II. Ed. (1915), fasc. 1–30. Grez-sur-Loing.

THWAITES, G. H. K. 1847. On conjugation in the Diatomaceæ. Ann. Mag. Nat. Hist. XX, p. 9, pl. iv, and p. 343, pl. xxii.

VAN HEURCK, H. 1880–85. Synopsis des Diatomées de Belgique. Anvers.

——— 1896. A Treatise on the Diatomaceæ. Trans. by W. E. Baxter. London.

——— 1909. Diatomées, in Résultats du Voyage du S.Y. Belgica en 1897–98–99. Exp. Ant. Belge. Botanique.

VANHÖFFEN, E. 1897. Die Fauna und Flora Grønlands. Grønland-Expedition der Gesellschaft fur Erdkunde zu Berlin, II. Berlin.

WALLICH, G. C. 1860. On the Siliceous Organisms in the Digestive Cavities of the Salpæ. Trans. Micr. Soc. N.S. VIII. London.

WEST, G. S. 1916. Algæ, I (including Bacillariales). Cambridge Botanical Handbooks.

——— and FRITSCH, F. E. 1927. A Treatise on the British Freshwater Algæ. Cambridge.

WEST, T. 1860. Remarks on Some Diatomaceæ, New or Imperfectly Described, and a New Desmid. Trans. Micr. Soc. N.S. VIII. London.

WULFF, A. 1925. Nannoplankton-Untersuchungen in der Nordsee, etc. Arbeit. d. deutsch. wiss. Komm. für Meeresforsch. B. Aus d. Biol. Anst. auf Helgoland, No. 31.

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EXPLANATION OF THE PLATES.

Plate 1

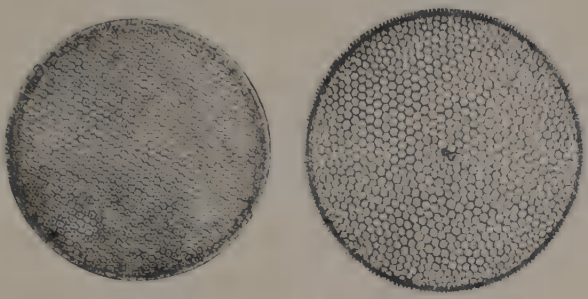
PLATE I.

FIG.

1. *Melosira hyperborea* (Grun.), with resting spores. After Gran, 1900*c*.
2. (*a*) *Coscinodiscus leptopus* Grun. After H. Van Heurck.
   (*b*) *Coscinodiscus nodulifer* Jan. After A. Schmidt.
3. *Coscinodiscus commutatus* Grun. After Ostenfeld, 1908*a*.
4. *Coscinodiscus stellaris* Roper. After A. Schmidt.
5. *Planktoniella sol* (Wallich). After A. Schmidt.
6. *Actinoptychus splendens* (Ehr.) After Péragallo, 1897–1908.

PLATE I.

Fig. 1.



a Fig. 2. *b*

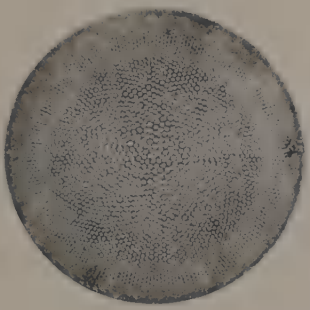


Fig. 3.

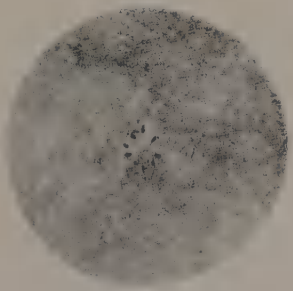


Fig. 4.

Fig. 5.

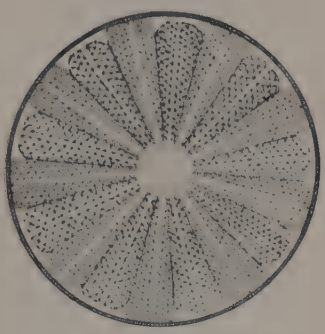


Fig. 6.

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Plate 2

PLATE II.

FIG.

1. *Actinocyclus Ehrenbergi* Ralfs. After Péragallo, 1897–1908.
2. *Actinocyclus Ralfsii* (W. Sm.). After Péragallo, 1897–1908.
3. *Eupodiscus argus* Ehr. After Péragallo, 1897–1908.
4. *Euodia cuneiformis* (Wallich). After Péragallo, 1897–1908.
5. (*a*) *Thalassiosira gravida* Cleve, after Meunier, 1910, showing resting spores. (*b*) *Thalassiosira rotula* Meunier; after Meunier, 1910, showing resting spores. (*c*) *Thalassiosira fallax* Meunier, after Meunier, 1910, showing resting spores.

PLATE II.

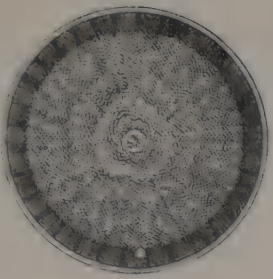

FIG. 1.

FIG. 2.

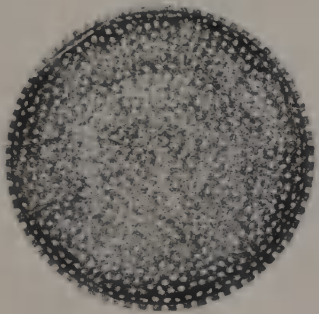

FIG. 3.

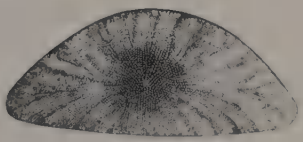

FIG. 4.

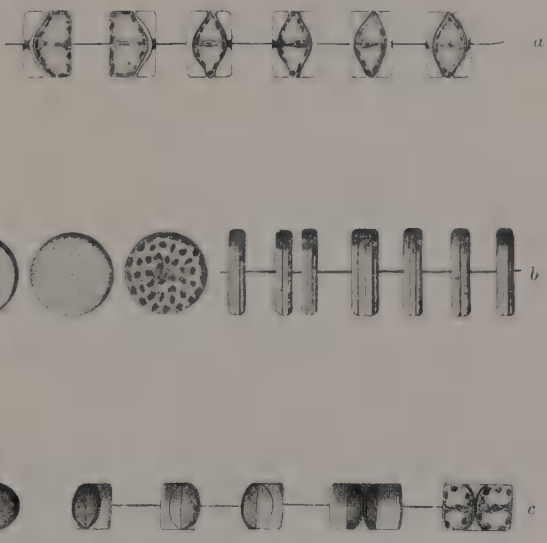

FIG. 5.

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Plate 3

PLATE III.

FIG.

1. *Coscinoscira Œstrupi* Ostenf. After Karsten, 1907. From Indian Ocean.
2. (*a*) *Bacteriastrum elongatum* Cleve. After Pavillard, 1925. (*b*) *Bacteriastrum solitarium* Mangin. After Mangin, 1912.
3. *Biddulphia Biddulphiana* (Smith) Boyer. After W. Smith, 1856.
4. *Biddulphia arctica* (Brightw.). After Meunier, 1910.

PLATE III.

FIG. 1.

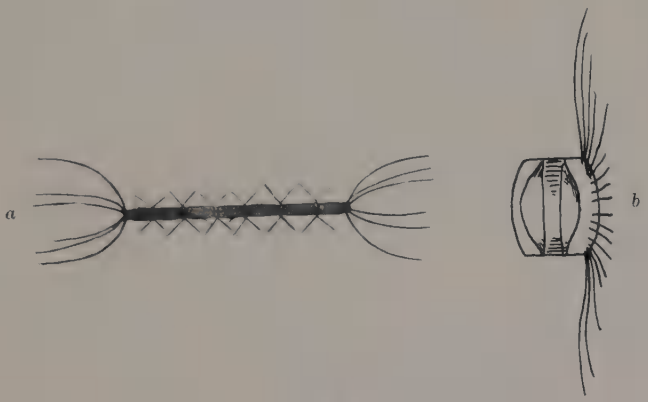

FIG. 2.

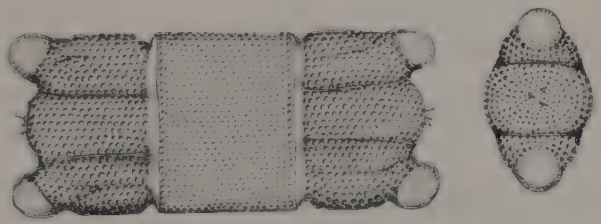

FIG. 3.

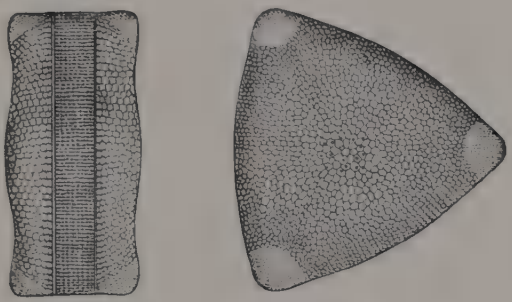

FIG. 4.

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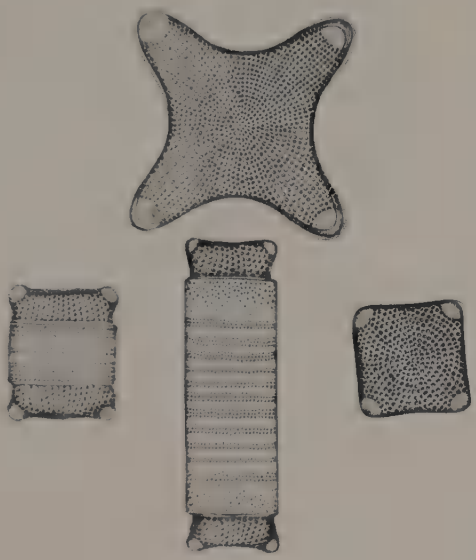
Plate 4

PLATE IV.

FIG.

1. *Biddulphia vesiculosa* (Ag.). After W. Smith, 1856.
2. *Cerataulus Smithii* Ralfs After Péragallo, 1897–1908.

PLATE IV.



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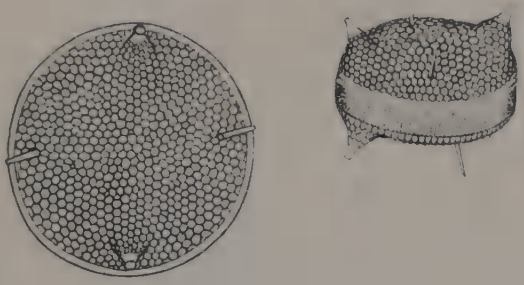

FIG. 2.

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